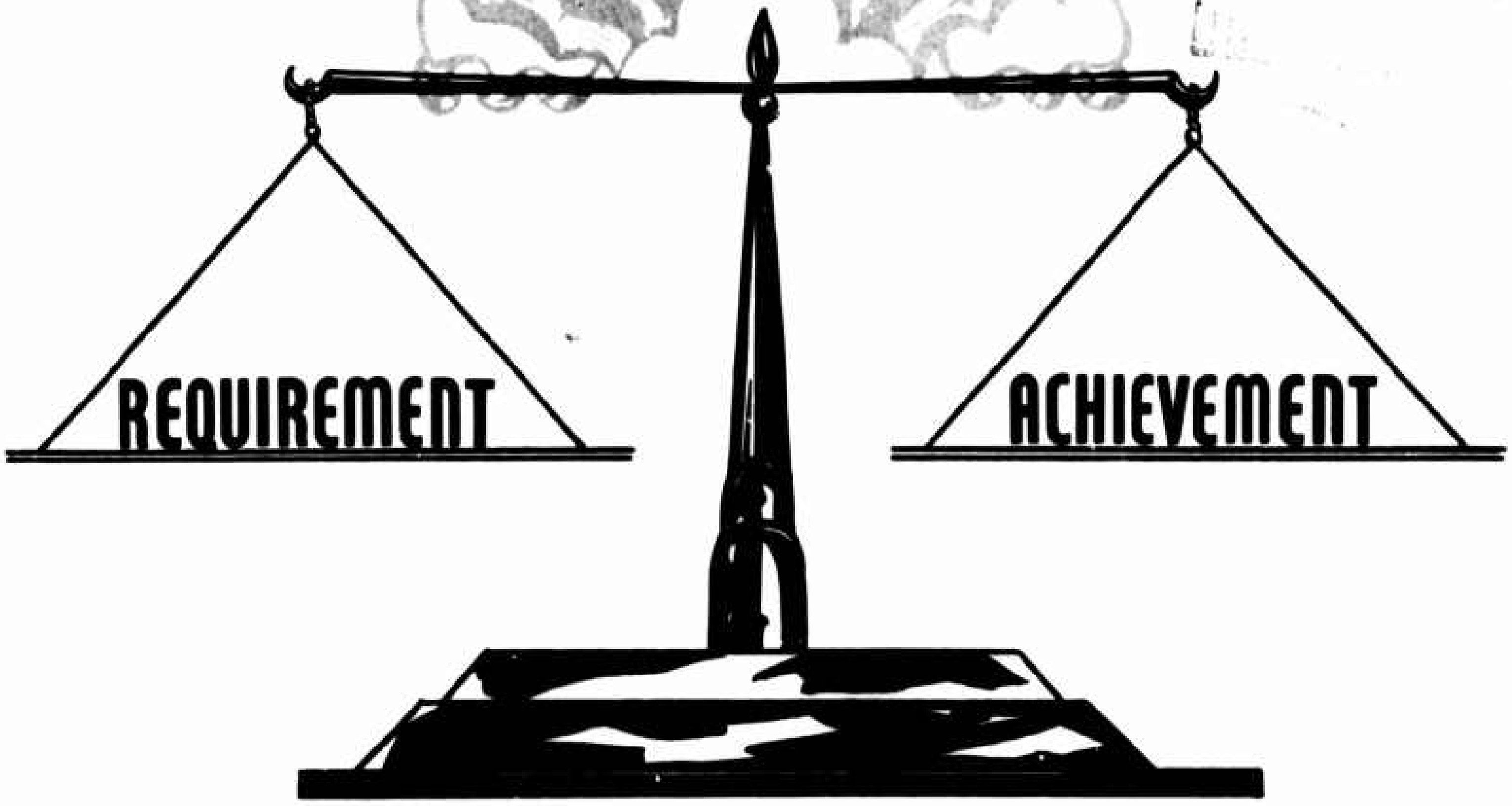
LINE OF BALANCE TECHNOLOGY

A GRAPHIC METHOD OF INDUSTRIAL PROGRAMMING



OFFICE OF NAVAL MATERIAL • DEPARTMENT OF THE NAVY

NAVEXOS P1851 (Rev. 4-62)

41

LINE OF BALANCE TECHNOLOGY

Reviewed and Approved 17 April 1962

Asst. Chief of Naval Material (Field Operations)

Introduction

WHAT IT IS

Line of Balance is a technique for assembling, selecting, interpreting and presenting in graphic form the essential factors involved in a production process from raw materials to completion of the end product, against a background of time. It is essentially a management-type tool, utilizing the principle of exception to show only the most important facts to its audience. It is a means of integrating the flow of materials and components into manufacture of end items in accordance with phased delivery requirements.

WHAT IT DOES

It relates actual status of the elements of a production program to planned progress. It identifies those elements which are lagging prior to delay in delivery of the end item.

It sets forth time relationships between various elements in the manufacturing process and points out deficiencies in the availability of materials, parts and assemblies at selected control points along the production line.

It provides an indication as to how well the various phases of manufacturing are synchronized.

WHAT IT IS USED FOR

Its basic use is to measure the current relationship of production progress to scheduled performance and to predict the feasibility of accomplishing timely deliveries.

It is a positive means for determining those areas of the process which need corrective action. Successively updated studies provide checks on the effectiveness of remedial action.

It is used as a basis for scheduling of purchase orders and shop orders.

It is extensively used by the Navy as a reporting medium or as a means of communication with the contractor.

Contents

SAMPLE LINE OF BALANCE CHART

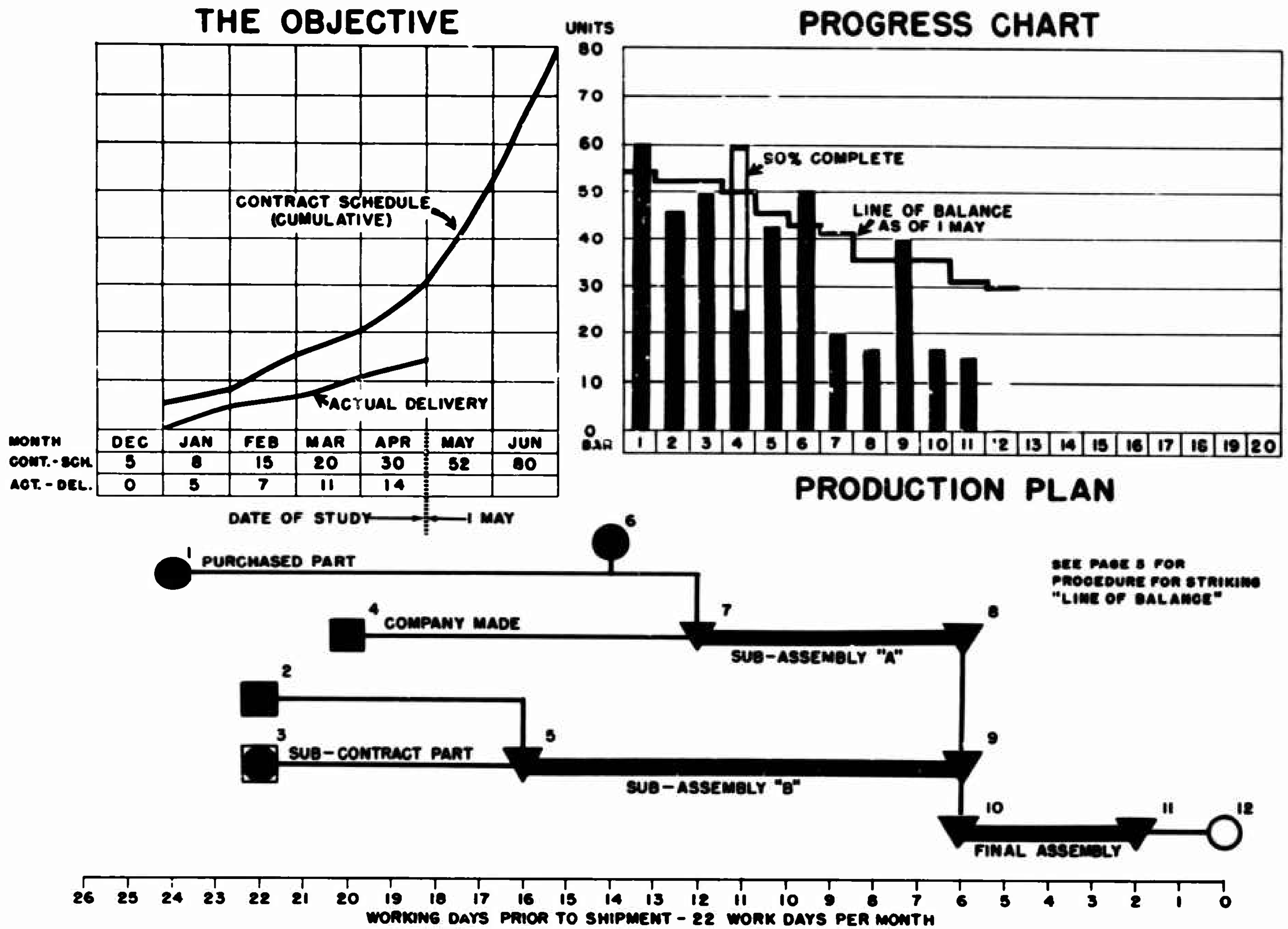


PLATE NO. 1

Part I

Elements of a Line of Balance Study

The Line of Balance (LOB) technique is comprised of the following four (4) elements or phases listed in the sequence in which each is normally developed when conducting a Line of Balance study of a production process.

THE OBJECTIVE—the cumulative delivery schedule.

THE PROGRAM—the production plan.

PROGRAM PROGRESS—the current status of performance.

COMPARISON OF PROGRAM PROGRESS TO OBJECTIVE—the Line of Balance. Plate No. 1 is a sample Line of Balance chart.

Section I—The Objective

The objective of a production process, where the end item is being produced under contract, is the required delivery schedule. The delivery information used and needed in a Line of Balance analysis is of two kinds, planned and actual.

PLANNED—the contractual delivery requirement.

ACTUAL—the delivery actually made by the producer to the time of the analysis.

Planned delivery and actual delivery are always collected and plotted in cumulative terms of end item sets.

ACCUMULATION OF DATA: Normally, contract delivery schedules are not cumulative. Therefore, the schedule must be extracted from the contract and converted to cumulative end items per unit of time. In addition, the contract and amendments should be examined carefully for revisions or changes to the schedule. If the Line of Balance study is to include production of identical end items for more than one contract, the objective should be the overall cumulative delivery requirements. If a proposed or revised schedule is used as the ultimate objective, it should be so labeled. If various departments within a contractor's organization appear to be working to delivery schedules other than the required contract schedule, these should be plotted on the same chart to indicate the discrepancy.

Actual delivery data is obtained from delivery records.

CHART CONSTRUCTION: Chart portrayal of the objective is accomplished by a simple graph using cumulative completed units plotted against time. The actual deliveries are plotted on the same graph.

Section II—The Program

Following the setting down of the objective, the second important step in a LOB study is to chart the program. The program, as used herein, is defined as the producer's planned process of production. Deriving the production plan or "assembly tree", in terms of key plant operations or assembly points, and their lead-time relationship to final completion, is the most vital stage in a Line of Balance study. These operational points are steps in the manufacturing cycle, the completion of which can be used to monitor intermediate progress of production toward its ultimate goal. Charting of the production plan results from detailed study, collectively, by plant management, the process engineering staff, and other representatives responsible for conducting the Line of Balance analysis. It is the heart of this and all other production surveillance techniques. Plate No. 1 contains a sample production plan.

ACCUMULATION OF DATA: The plan should cover the span of operations peculiar to the particular manufacturing process, from work on raw materials through assembly operations to point of shipment. Prior to any detailed examination or storing and categorizing of data supplied by the contractor, a tour should be made of the plant to observe the physical layout, and the actual processes involved, as well as to observe the physical attributes of the operations. This trip should be made "in reverse," beginning at the shipping room door and ending at the stockroom where incoming materials are received. This unusual approach will enable the observer to obtain a more accurate concept of the entire production plan and is essential in order to establish an accurate concept of lead time for operations and materials.

As a further basis for developing the information necessary for the production plan, the guides which the manufacturer has developed in order to produce should be utilized to the utmost. These frequently consist of:

a. Shop drawings
b. Bills of Material — See Plate No. 2
c. Process Charts
d. Machine Loading Charts
e. Assembly Line Layouts
f. Shop Orders

The production plan, or "assembly tree" data is developed from *three* aspects:

1. THE DETERMINATION OF OPERATIONS TO BE PERFORMED:

A determination is made of various operations to be performed on major components, purchased parts, company-furnished parts, Government-furnished parts, subcontracted parts and raw materials. Using the principle of monitoring by exception, only the key operations plus other potentially limiting steps need be considered for the production plan. Care should be exercised to eliminate as many as possible of the simpler, less troublesome operations. However, this should not be carried any further than compatible with sufficient coverage. In cases where rapidly consecutive operations of an allied nature can be grouped or where associated parts can be grouped and named as a single one, this should be done. The parts of the production plan selected for study are not stereotyped, nor are they standardized in number, but may vary considerably as determined by local knowledge of the manufacturing process or by availability of material at the time of study.

2. THE DETERMINATION OF THE SEQUENCE OF OPERATIONS:

This involves the determination of the sequence, or order in which the parts and hence the subassemblies are directed into the final assembly stage.

The first step is to examine the list of parts shown on the Bill of Material. They are usually arranged according to the major assemblies which, in turn, are further divided into subassemblies. A general chronological determination of flow can be made at this stage concerning the approximate sequence, or order, in which these materials and subassembly groups flow into final assembly operations. This should then be consolidated onto a flow chart which will delineate the steps of the process in sequence.

3. THE DETERMINATION OF PROCESSING AND ASSEMBLY LEAD TIME

This involves a determination of the total time interval, in each case, between the ***required availability*** of raw material, purchased parts, manufactured parts, subassemblies and the ***date of shipment of the completed end item.*** This time is inclusive, and in addition to required processing time it includes other aspects such as in-plant storage or handling time. In this manner, the time is established by which each operation, subassembly, or other event, must take place in advance of ultimate delivery of the end item. This is expressed in definite time units (weeks, days, etc.). The longest lead time for any one part within a subassembly group becomes the governing lead time for that entire subassembly group when constructing the production plan.

CHART CONSTRUCTION: Having determined the raw materials, parts, fabrication stages, subassemblies and assemblies with which the Line of Balance study is concerned, and having obtained the applicable sequence of operations and lead time information, the data is presented graphically in the following manner:

The production plan or assembly tree is constructed by using a time scale in units commensurate with the overall lead time. The time scale is normally set down in working days rather than

INFORMATION FOR PREPARING PRODUCTION PLAN

SHAFT AND GEAR SUB-ASSEMBLY

A SHAFT
B GEAR
C KEY
D WASHER
E NUT

BILL OF MATERIAL

NO.	DESCRIPTION	SIZE OF SPECIFICATIONS	UNITS	TYPE	MISC.
152	GEAR & SHAFT ASS'Y.				
1521	Gear (Phos. Brz.)	1 1/8" thick x 3 1/4" dia.	1	CM	
1522	Shaft	1 3/4" x 9" C.F. C1117 Bar	1	"	
1523	Washer	2 1/4" dia. x 5/16" thick C.F. B1112 Bar	1	"	
1524	Nut	2"0 dia. x 3/4" thick C.F. C1117 Bar	1	P	
1525	Key	Commercial Material	1		

PROCESS SHEET

152 GEAR AND SHAFT ASSEMBLY

1521 GEAR

(a) Order gear blank from store to size desired, or cut to length on power saw
(b) Prepare for broaching by turning blank to fit cup on broach machine.
(c) Broach
(d) Return to lathe for finish turning
(e) Hob teeth on hobbing machine - or on especially equipped milling machine
(f) Bench work, file burrs, polish teeth, inspect and identify.

1522 SHAFT

(a) Cut to desired length on power saw
(b) Center
(c) Turn on lathe
(d) Mill or hob threads
(e) Mill key ways
(f) Bench work, file, burr, inspect and identify

1523 WASHER

(a) Cut to desired length on lathe or power saw
(b) Machine all over (on lathe)
(c) Grind faces to no. 32 finish (on grinder)
(d) Bench work, file, burr, inspect and identify

1524 NUT

(a) Cut to length, using lathe or power saw
(b) Turn bore for threads and face sides
(c) Mill or hob threads (If quantity is small, chase threads on lathe)
(d) Mill hex (If quantity is large, suggest setting up of triple head indexing equipment)
(e) Bench work, file, burr, inspect and identify

1525 KEY

(a) Commercial
(b) Fit to key ways on Shaft and Gear

FINAL

152 BENCH WORK

(a) Fit and assemble the Gear and Shaft Assembly Unit
(b) Inspect and identify

PLATE NO. 2

calendar days. A week, therefore, consists of 5 days and a month consists of 22 days, if the plant is operating on a 40-hour week.

For ease in interpretation, the production chart is coded by symbol, color, and number to indicate the type of operations being performed at each control point.

The production plan is developed by setting down the selected events and operations in their proper sequence, commencing at the point of delivery and moving backward through the entire production process. The control points are numbered from left to right and from top to bottom as shown on plate 1. This will usually result in four or more general sequential phases as follows: The final assembly process, preceded by major subassembly work, preceded by manufacture of parts, preceded by acquisition and preparation of raw materials and purchased parts.

In cases where there are a few long lead-time items and many short lead-time items or vice versa, a break should be indicated on the time scale for the production line so that two suitable scales may be used instead of only one. To put it another way, a segment of the scale may be magnified if this will make for clarity or convenience of plotting. When representing the lead time for a purchased or subcontracted or Government-furnished part, the symbol for that part should be placed at the number of days prior to shipment of the end item that the part must be available at the plant. When the lead time is for a company manufactured part, the symbol representing that part should be plotted at the number of days prior to shipment of the end item that the fabrication of the part must commence. Plate 1 contains a production plan.

Section III—Program Progress

Previous sections have thus far developed:

1. A graphic presentation of planned manufacturing goals.
2. A graphic presentation of the planned manufacturing process by which attainment of the delivery goal is contemplated.

This section explains the development of the program progress portion of the Line of Balance study.

The program progress element of the study pertains to the status of actual performance and is comprised of a bar chart which shows the quantities of materials, parts, and subassemblies available at the control points at a given time.

ACCUMULATION OF PROGRAM PROGRESS DATA: Program progress or production progress is depicted in terms of quantities of materials, parts, and subassemblies which have passed through the individual check points or control points of the production plan, including those contained in end items already completed. This information is accumulated by a physical inventory for each control point. The count is normally available from appropriate stock records, but if such is not the case a physical tally must be made. Whenever the contractor's stock control system is to be used, a physical spot check by actual count should be made in order to insure that the system is adequate and that it is being properly implemented. Program progress counts must not include defective or rejected quantities which will not add to the usable inventory. The count must be in end item sets and, therefore, must be factored whenever two or more units of an item are required in the completed assembly. When it is necessary to tally parts or components which are common to other manufacturing by the contractor, it will be necessary to make allotments from the overall availability of them. In cases where a single symbol or a single control point has been shown on the production plan to represent a family of operations or parts, the quantity tallied for that control point shall be the quantity of the least available of the members of that group or family. Likewise, whenever a control point represents the beginning of an assembly process (either subassembly or final assembly) the quantity tallied and used for that control point shall be the quantity of the least available component or part of that assembly or subassembly.

PROGRAM PROGRESS CHART CONSTRUCTION: On the program progress chart the same quantity scale is used as ordinate (vertical axis) as was used for the objective delivery chart. The abscissa scale (horizontal axis) corresponds by duplication of numbers, to the numbered control points depicted in the production plan. Numbering and coloring of the status or quan-

tity bars is keyed to correspond with and to duplicate the numbered control points of the production plan. Scale numbering in this instance proceeds from left to right progressively.

If it is desired to show that an appreciable quantity has been nearly completed in addition to that already completed at a given control point, the bar for that control point may be extended upward the appropriate amount but left uncolored. If this is done, an appropriate explanation should be made on the chart. Such bars are normally called ghost bars. Plate No. 1 contains a sample progress chart, on which bar No. 4 is a ghost bar.

Section IV—Comparison of Program Progress to Objective

Development of the objective, the program, and program progress completes the accumulation of physical information. There remains the task of relating the intelligence already gathered. This is accomplished by striking a "Line of Balance," which is the basis to be used for comparing the program progress to the objective.

The balance line quantity depicts the quantities of end item sets for each control point which must be available as of the date of the study to support the delivery schedule. In different words, it specifies the quantities of end item sets for each control point which must be available in order for progress on the program to remain in phase with the objective.

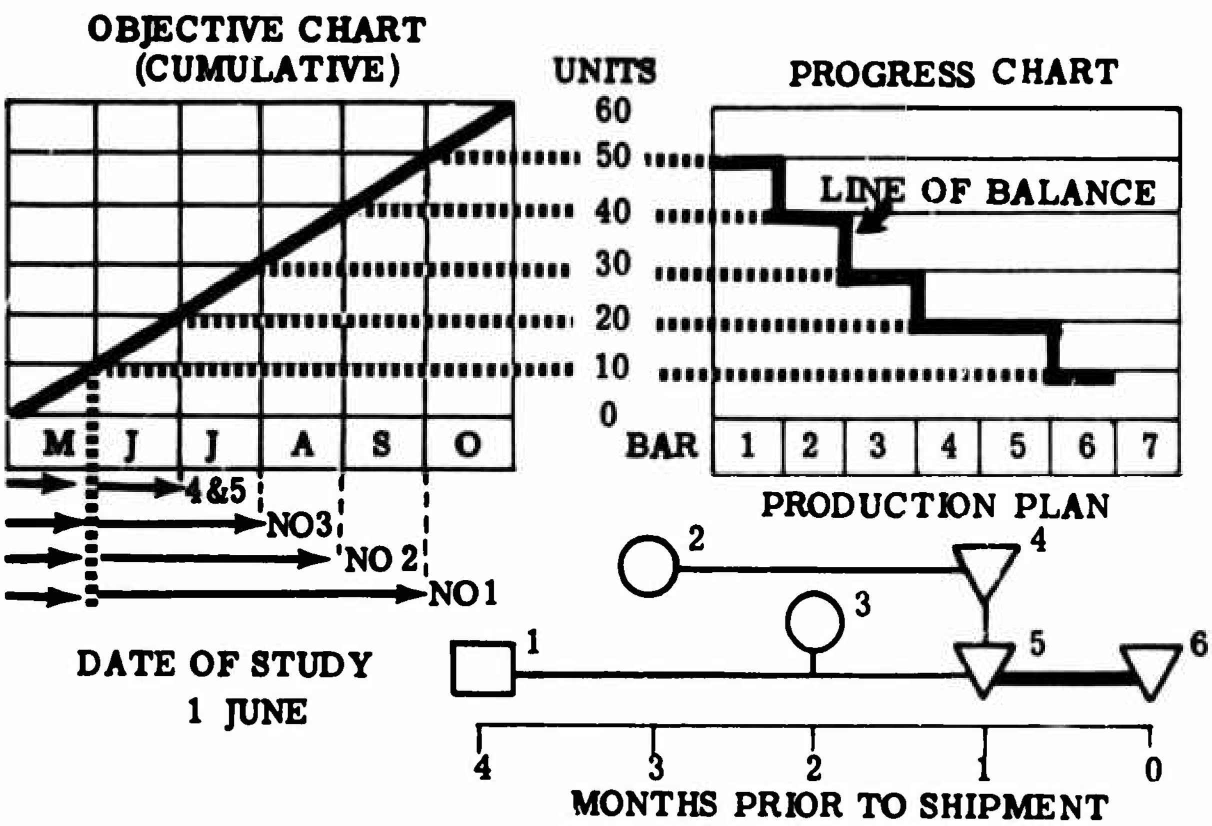
STRIKING THE LINE OF BALANCE: The procedure for striking the Line of Balance is as follows:

a. Plot the balance quantity for each control point:

1. Starting with the study date on the horizontal axis of the cumulative delivery (objective) chart, mark off to the right the number of working days (or weeks or months, as appropriate) of lead time for that control point. This information is obtained from the production plan.
2. Draw a vertical line from that point on the horizontal axis to the cumulative delivery schedule.
3. From that point draw a horizontal line to the corresponding bar on the progress chart. This is the balance quantity for that bar.

b. Join the balance quantities to form one staircase-type line across the face of the progress chart.

The following general sketch is illustrative of the procedure described above:



Part II

Conducting a Line of Balance Study

Section I—Consideration for Need

Consideration should be given to the need for a LOB study, in order to relate progress to objective, whenever delivery of high-priority end items lag or whenever there is an indication of potential delays. When late delivery of an end item will cause a corresponding delay in a strategically important program, or if it will cause a sharp increase in cost of a program, LOB serves as a positive device for avoiding or minimizing such effects. In addition, this technique should be considered for use in the following situations:

a. Where management needs a reporting medium which can be operated on an exception basis and yet positively bring limiting factors into focus.

b. When there is need for a means of synchronizing phased deliveries of incoming materials, components and subcontracted parts with the in-plant manufacturing. This is always beneficial, but it is particularly necessary in cases of limited funds or a shortage of storage area.

c. When it is known that the original delivery schedule will not be met and there is a need to insure that the revised delivery dates are realistic by relating current progress to a revised or proposed delivery schedule.

The Navy has been able to apply the technique successfully to such a wide variety of situations that it appears the method can be used for production surveillance in almost all instances. The applications of the technique which have demonstrated its great adaptability and power have been those which pertained to complex end items emanating from complicated production processes involving long lead times.

When management of a manufacturing concern or of an industrial installation of the military departments has decided to conduct a LOB study on a specific project, the next step is to assign the tasks. However, in those cases where a customer, such as a purchasing activity of a military department, desires a LOB study, the consent and cooperation of the contractor must be obtained in order to initiate the joint effort. In some instances it even becomes necessary to make a formal presentation in order to point out that:

a. A completed study will readily show the feasibility of meeting the contract delivery schedule, including an indication of trend.

b. In particular, if deliveries have not commenced the LOB will indicate whether or not initial deliveries will be on schedule.

c. If shipments have already commenced and are in arrears, comparison of the "actual deliveries curve" with the objective curve will give an indication of the trend toward further slippages from the original schedule or of a tendency to maintain a constant lag.

d. Also, shortages at various control points are indicative of problem areas and, therefore, point out to management those segments of the manufacturing process which require emphasis from the top as well as additional effort at lower echelons.

Section II—Preparation

A minimum of two people is required to conduct a Line of Balance study, but a group, or "team" of four members is not uncommon. Four to seven working days are normally required. The size of the study group is best governed by the size and complexity of the pro-

posed study. Leadership of the team must be vested in one person who will be directly responsible for the entire study, from arranging for suitable work space to organizing the survey presentation and resultant recommendations, as well as all intermediate steps. It is essential that neither the group leader nor any of his team have any line responsibility for production of the end item. This has the obvious advantage of eliminating any pre-established convictions or bias which might prejudice the effectiveness of the study. At the same time, however, it is desirable that all be familiar with general industrial practices. Some basic knowledge concerning the production plan under survey would be helpful but not essential because the specific production plan is determined during the course of the study. Sound practice dictates that team members be experienced in making a Line of Balance study. It is not always possible, however, to have enough trained personnel; therefore, in some cases it is necessary for the leader to indoctrinate his less experienced workers before actually beginning the study. Here again, the leader must be especially well qualified to serve in the dual capacity as organizer and instructor, for all participants must know the general principles of the Line of Balance technique.

Each member of the team should be assigned specific responsibilities in connection with collecting, tabulating, and evaluating and plotting information. The data required will originate in many departments, such as planning, purchasing, engineering, receiving, production, stock control, inspection and test; and arrangements should be made for liaison between all contributing departments and the survey team. Regardless of the experience of any or all of the team on production similar to that to be studied, all should make a thorough inspection trip through the plant to obtain a first-hand concept of the overall process. By starting the tour at the shipping department the end item will be seen first at the end of the final operation. As the tour progresses in reverse, each assembly operation is observed, each component and part is seen, and the Production Plan, the heart of the endeavor, commences to unfold. Such a plant tour will reveal immediately key situations to experienced analysts, and serve to prime the neophytes. So valuable is such a tour that even plant employees who are participating should avail themselves of this specific opportunity, for seldom can one individual know everything about all things, even in his own plant.

Next, arrangements should be made for the survey group to be given as complete a bill of materials as is available as well as shop orders, procurement schedules, machine loading records, process charts, etc. The applicable specifications and drawings, and even an organization chart of the company (this is frequently very useful) should be available. Very little, if any of this data will ever turn out to be extraneous. Most of it will be available readily, in one form or another in nearly every case.

Section III—A Sample Study

The detailed steps involved in the construction of a LOB chart as set forth in Part I should be followed closely. The following case is a study which was made on a synchronous motor.

The ABC Company was recognized by the Navy as a reliable manufacturer of equipment and, as such, having met all precontractual requirements was awarded a contract on 1 January 1953 by the Navy to manufacture fifty (50) Synchro Motors within a 4-month period.

Delivery of the motors was scheduled by contract to be as follows: Beginning with April 1953—quantity of ten (10) per month through August 1953, inclusive. However, as the contractor proceeded with the manufacture of the motors, the usual Synchro Motor symptom troubles began to appear; dirty bearings, broken and damaged wire insulation, out-of-true housings, etc. After 7 months of trial and effort to produce the motors the contractor requested a revision in the delivery schedule as follows: 10 motors in October, 20 motors in November and 20 motors in December 1953. Before any decision was made regarding the change in delivery proposal, the Navy suggested that "due to the urgency of the end item," both the Navy and the contractor should investigate fully the feasibility of the new delivery promise of the contractor.

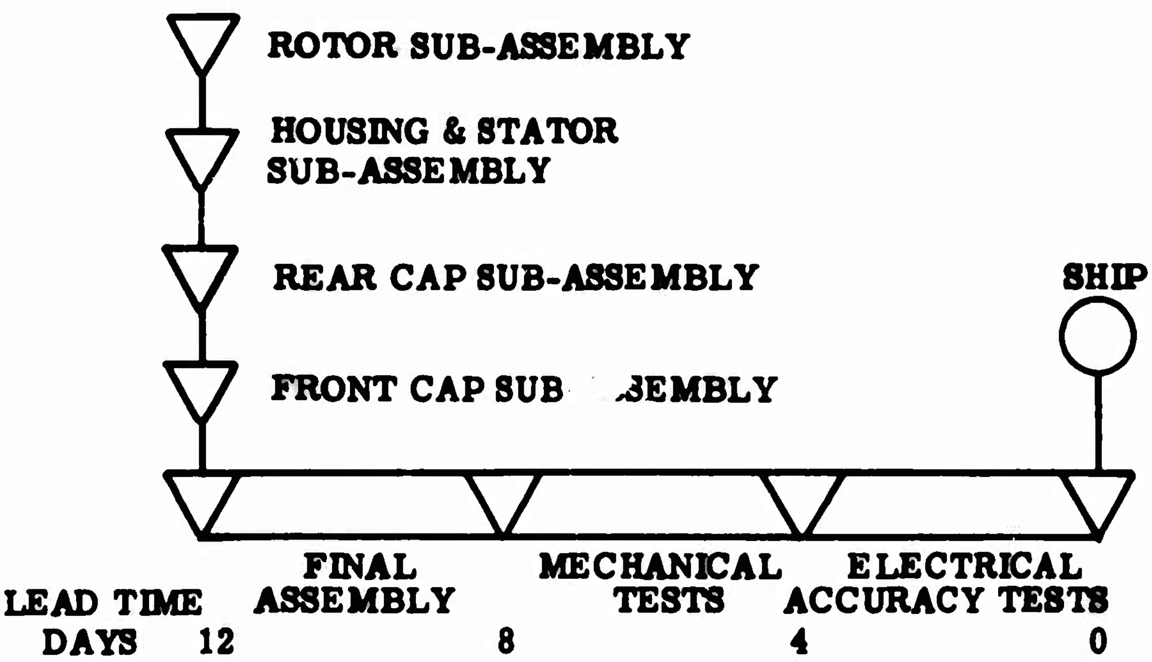
During the process of examining the Company's facilities and know-how to produce Synchro Motors, it was agreed that a Line of Balance

study be made in order that obvious production bottlenecks be brought to the attention of top management where decisions could be made to improve the problem areas.

The study took place 31 October 1953. At that time five motors had been shipped.

Inspection of the physical plan of production established that:

1. The manufacture of the end item, from the release of raw materials to final shipment, covered an estimated cycle of 41 working days. During this 41-day period the Synchro Motor was fabricated from raw material, progressing through various phases of manufacturing and processing operations, into related subassembly groups, to completion.
2. The beginning of the final assembly line occurred at 12 days before shipment. Only the first 4 days of this period were required for actual assembly. The remaining 8 days covered testing, acceptance, and final shipment.
3. The end item was composed of 4 subassembly groups called the rotor, housing-stator, rear cap and front cap assemblies. Each of these and their constituent components, passed through certain processing operations and inspection before they joined at final assembly. The tie-in of the 4 subassemblies to the beginning of the final assembly line was readily discernible as shown in the following sketch:



The detailed data which was developed and the resulting LOB chart (Plate No. 3) are shown on subsequent pages.

PE—Purchased equipment.
CM—Company-made.
SC—Subcontracted.

Nomenclatures, subassemblies, plans of operations by lead times and stock status

Subassembly groups	Type	Names/operations	Lead time days for availability of materials and processing operations: Materials	Begin work	Finished or available	Number on hand, in use or processed, quantity
Hardware	PE	Miscellaneous hardware for assembly of motors.	31		12	42 complete sets.
Rotor subassembly						
Coil	PE	Wire	35		17	50 materials.
Jam collar	CM			33		50 started.
					21	38 finished.
Laminations	CM	Rotor set, punch, heat-treat, cement, stack, bake, inspect.	41			50 materials in.
				31		50 started.
					21	38 finished.
Collector ring assembly.	SC	Collector ring assembly	29		21	50 available.
Shaft	CM	Fabricate	41			50 materials in.
				31		40 started.
					21	36 finished.
Assembly	CM	Assemble shaft with laminations, collector ring assembly and jam collar.	21			36 started.
					17	30 completed.
Assembly	CM	Wind coils, test, impregnate, bake, grind O. D. and I. D. with bearings in position on shaft, spray with glyptal-progressive electrical tests, as required.		17		26 started.
					12	20 completed.
Housing-stator subassembly						
Coil	PE	Wire-wind-test	35			50-wire available for 50 coils.
				25		50 coils started.
					23	50 coils wound and inspected.
Laminations	CM	Stator set punch, heat-treat, cement, stack, bake, inspect.	41			50 raw materials in.
				31		50 started.
					23	35 finished.
Stator lamination sets	CM	Insulate, insert coils, impregnate, grind O. D. and I. D. progressive electrical tests, as required.		23		33 stators started.
					17	24 stators finished.
Housing	CM	Raw material	37			50 raw materials.
		Begin machine work		27		30 started machine.
		Finished machine work			17	22 finished machine.
Housing and stator assembly.	CM	Assembly, fit		17		22 started.
		Housing and stator			12	16 completed.
Rear cap subassembly						
Bearing set	PE	Bearing set	21		14	50 available.
Terminal block brush assembly.	SC	Terminal block and brush assembly.	21		14	46 available.
Rear end cap	CM		35			50 materials available.
				24		34 started machine.
					14	25 finished machine.
Assembly	CM	Assemble		14		25 started assembly.
					12	21 finished.

Nomenclatures, subassemblies, plans of operations by lead times and stock status—Continued

Subassembly groups	Type	Names/operations	Lead time days for availability of materials and processing operations			Number on hand, in use or processed, quantity
			Materials	Begin work	Finished or available	
Front cap subassembly						
Bearing sets	PE	Bearings	21	......	14	50 sets available.
Front end cap	CM	......	35	......	......	50 raw materials.
				24	......	36 started machine.
					14	24 finished machine.
Assembly	CM	Assemble	......	14	......	24 started in assembly.
					12	19 finished in assembly.

Final assembly of motor: 15 started in final assembly. 10 started in mechanical tests. 8 started in electrical accuracy tests. 5 motors completed. 5 motors shipped.

NOTE.—For final assembly from 12 days to shipping point see final assembly line data on p. 8.

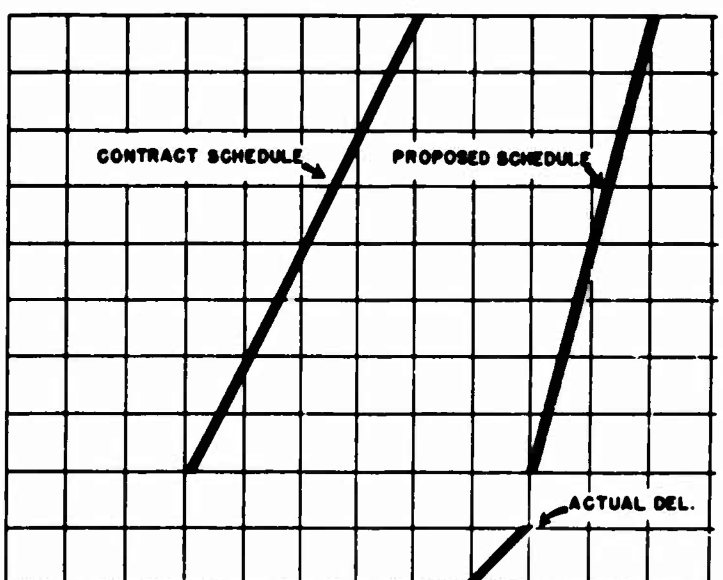
INDUSTRIAL PROGRAMMING LINE OF BALA

THE A B C COMPANY

MOTOR

CONTRACT NO. N1236-0700
UNITS IN CONTRACT 50
CONTRACT DATE 1 JAN 1953

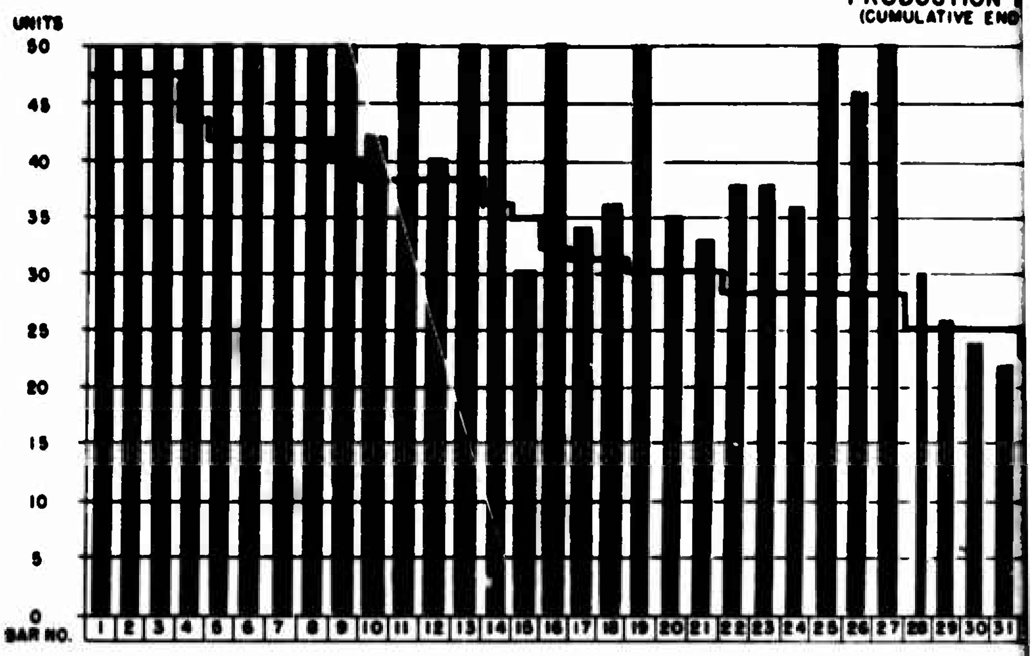
CUMULATIVE DELIVERY SCHEDULE
(OBJECTIVE)



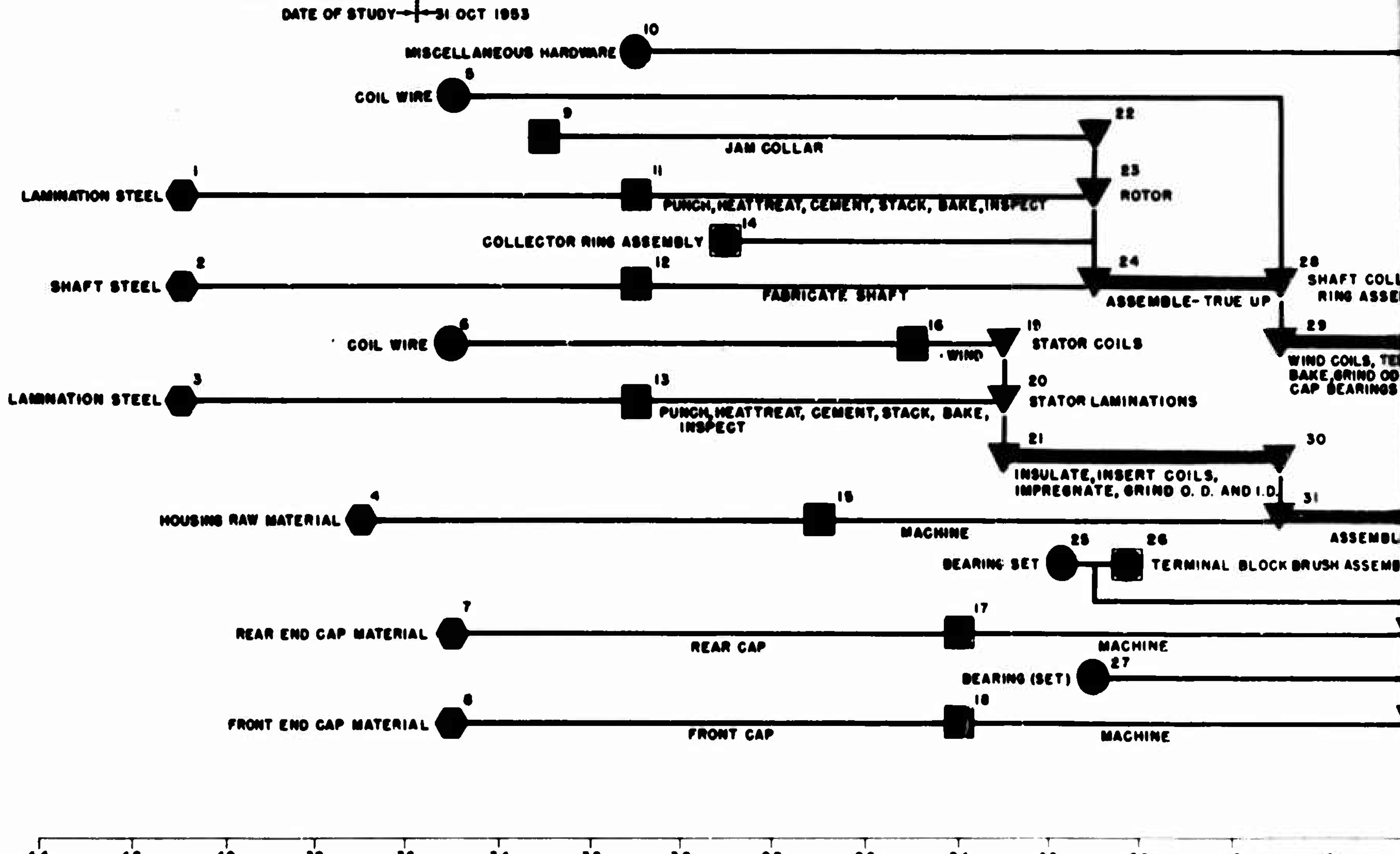
FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN
		10	20	30	40	50	CONTRACT SCHEDULE				
			PROPOSED SCHEDULE					10	30	50	
			ACTUAL DELIVERY					5			

DATE OF STUDY 31 OCT 1953

PRODUCTION
(CUMULATIVE END



PRODUCTION
(SCHEDULED FLOW OF MATERIAL



OFFICE OF NAVAL MATERIAL
U. S. NAVY DEPARTMENT

WORKING PERIOD PRIOR TO SHIPMENT
22 WORKING DAYS PER MONTH

PLATE NO. 3

A

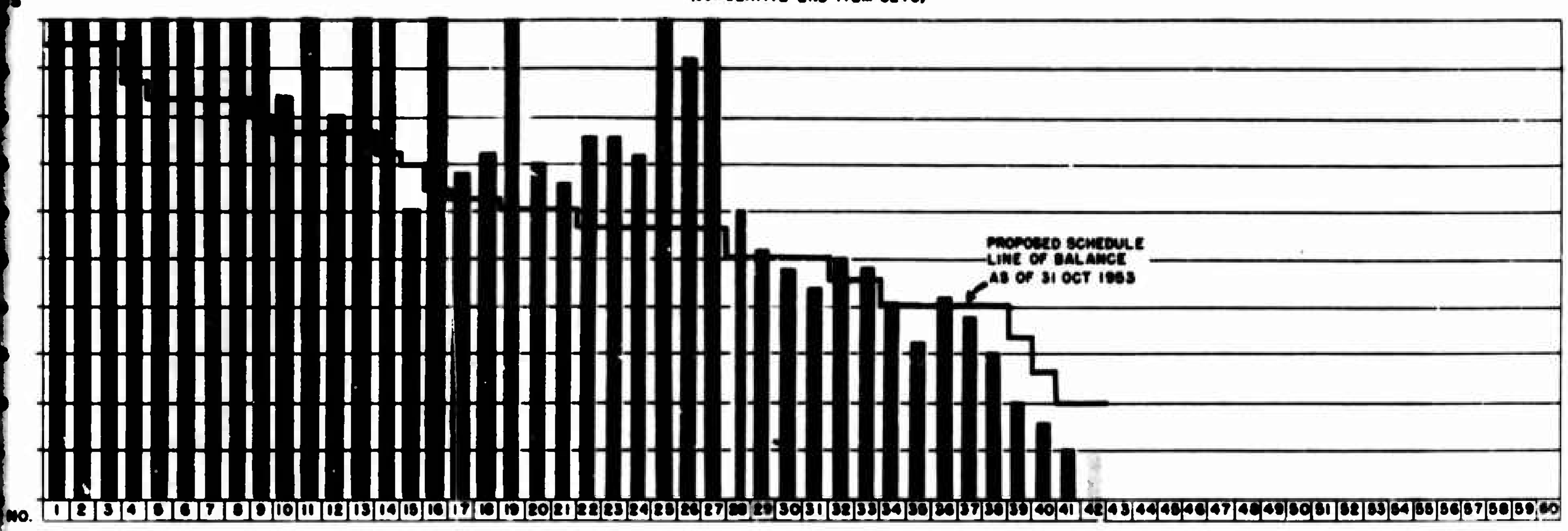
TRIAL PROGRAMMING LINE OF BALANCE CHART

THE A B C COMPANY

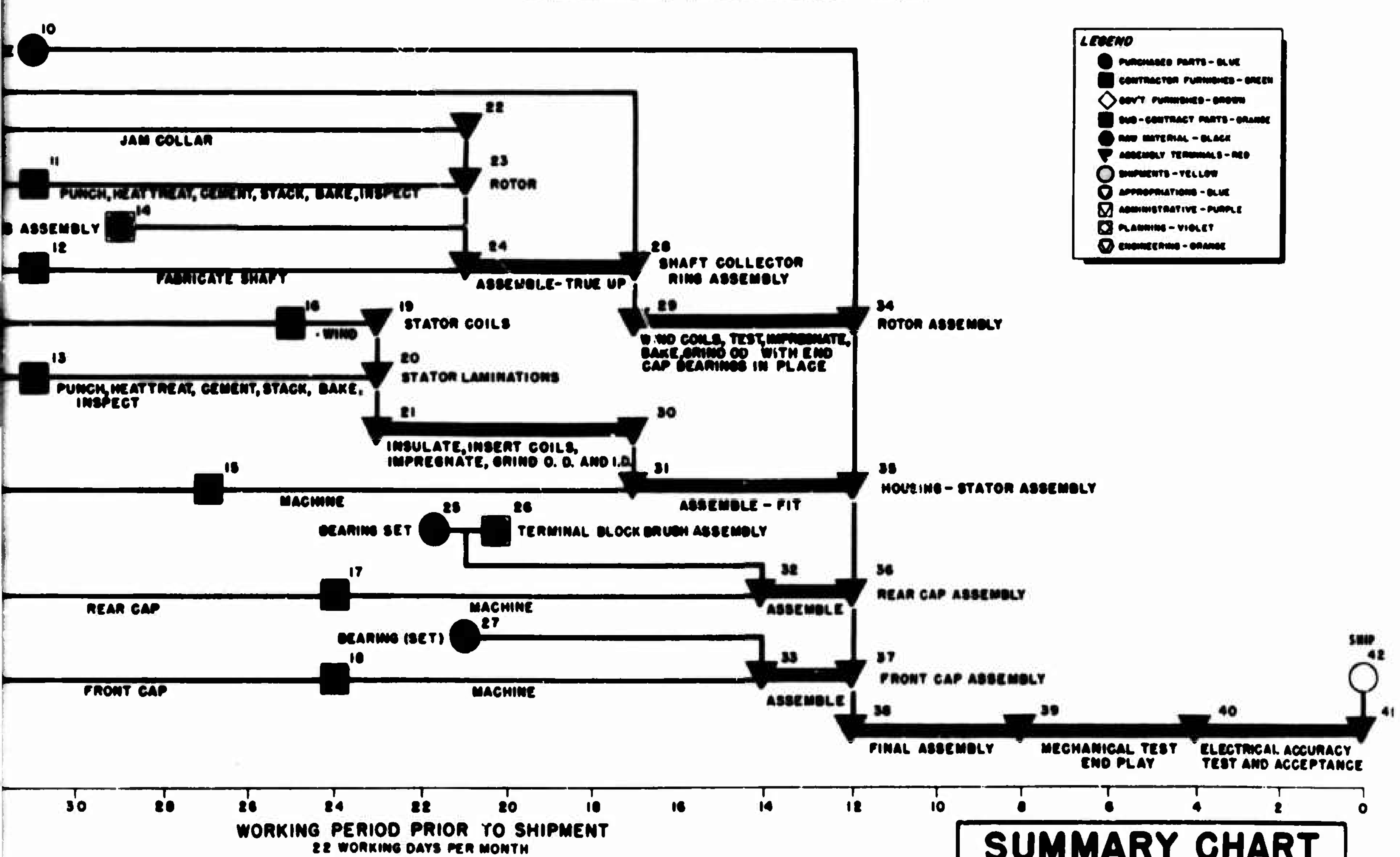
MOTOR

CHART NO. 1 OF 1
DATE 31 OCT 1953

PRODUCTION PROGRESS
(CUMULATIVE END ITEM SETS)



PRODUCTION PLAN
(SCHEDULED FLOW OF MATERIALS, COMPONENTS & PARTS)



SUMMARY CHART

PLATE NO. 3

B

Section IV—Supplementary Charts

On occasions it will turn out that even though a single general chart will point out areas of deficiency, further expansion and highlighting of the lagging segments will assist management in focusing on the exact problems. There are two ways of accomplishing this, either by means of using subassembly charts or by using source type charts.

In order to prepare a chart for a specific subassembly, the objective employed is the required availability schedule for that subassembly. The production plan is comprised of a detailed derivation of the fabrication of the subassembly concerned. The progress chart corresponds to the control points on the production plan. Plates No. 4 and No. 5 are illustrative of a general chart and a major subassembly, respectively.

In unusually complex cases, charts can be made according to the source type of parts and components. Such charts may be for contractor-made, purchased, Government-furnished or subcontracted parts. For purposes of LOB charts, a purchased part is considered to be one which is procured as a commercial type commodity, frequently off the shelf, from stock or from normal mass-type production; whereas a subcontracted part is one which is to be manufactured to a definite specification or drawing in a job lot for the particular end item. In constructing a source type chart, the same objective is employed as that which was used for the general overall chart. The same production plan is also used except as is necessary to modify it in order to add control points for additional items of the specific source type and in order to delete control points for items not of that specific source type. The progress chart corresponds to the control points on the production plan.

This latter method is particularly advantageous where the end item is comprised of thousands of parts and where the end item cannot easily be factored into a small number of distinctively separate subassemblies. When there are more components of a given source type than can be conveniently posted on a single chart, it is necessary to draw up the production plan to show the flow pattern of related groups or families of parts, which are received or fabricated or installed at essentially the same point in the manufacturing cycle. In order to establish the lead time of any group, it is necessary to consider the individual parts which make up the group, and if there are different lead times for these separate parts, that of the earliest required piece should be used for the group. This applies of course to the production plan and to the computation of the balance line. On the other hand in posting the stock status on the progress chart, the count of that component within the group which is in shortest supply should be shown, as this least available item is the controlling one in each group. Plate No. 6 is a sample source type chart (purchased parts).

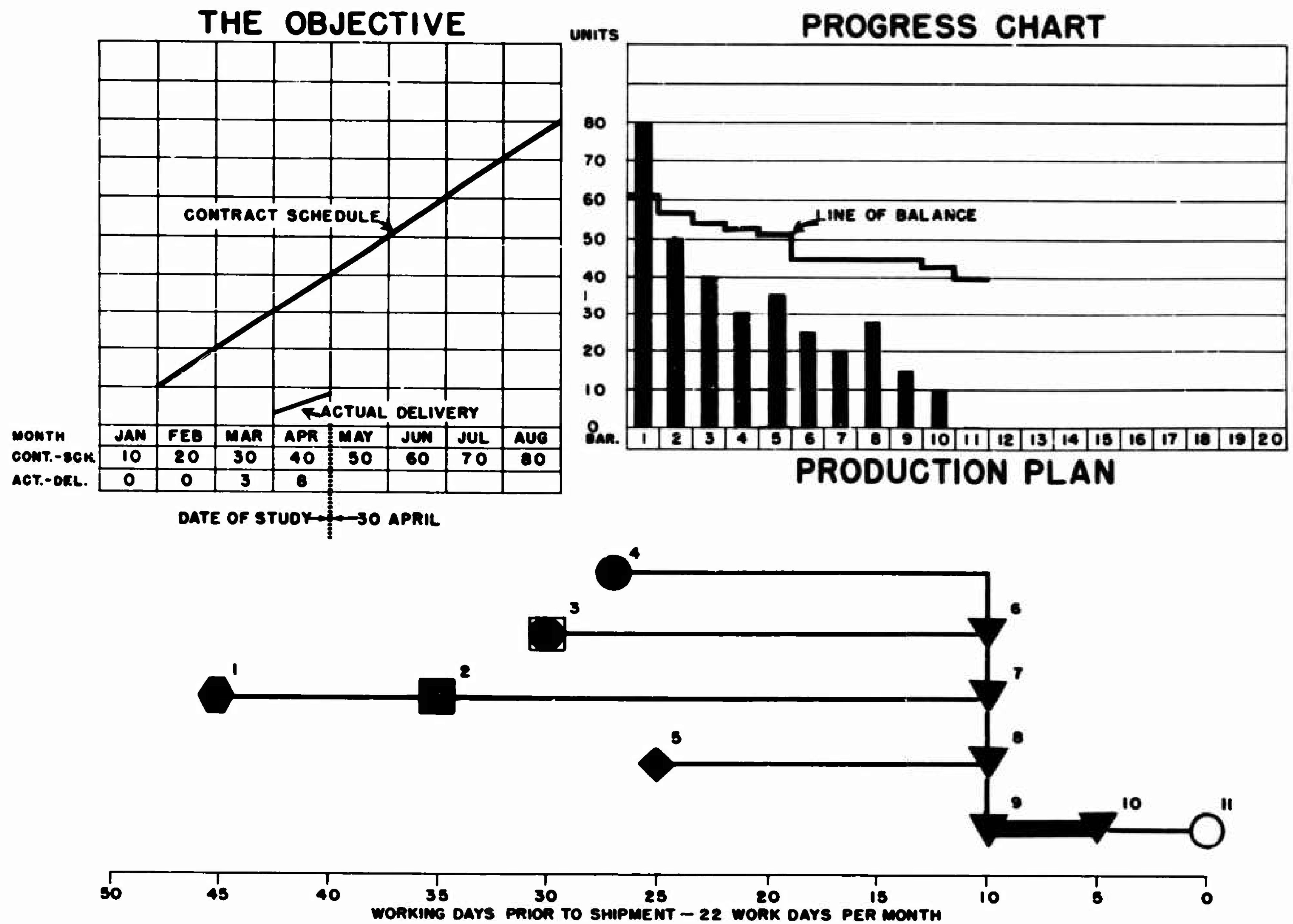

THE OBJECTIVE
CONTRACT SCHEDULE
ACTUAL DELIVERY
MONTH
CONT.-SCH.
ACT.-DEL.
JAN FEB MAR APR MAY JUN JUL AUG
10 20 30 40 50 60 70 80
0 0 3 8
DATE OF STUDY—30 APRIL
PROGRESS CHART
UNITS
80
70
60
50
40
30
20
10
0
BAR.
LINE OF BALANCE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PRODUCTION PLAN
1
2
3
4
5
6
7
8
9
10
11
50 45 40 35 30 25 20 15 10 5 0
WORKING DAYS PRIOR TO SHIPMENT — 22 WORK DAYS PER MONTH

PLATE NO. 4

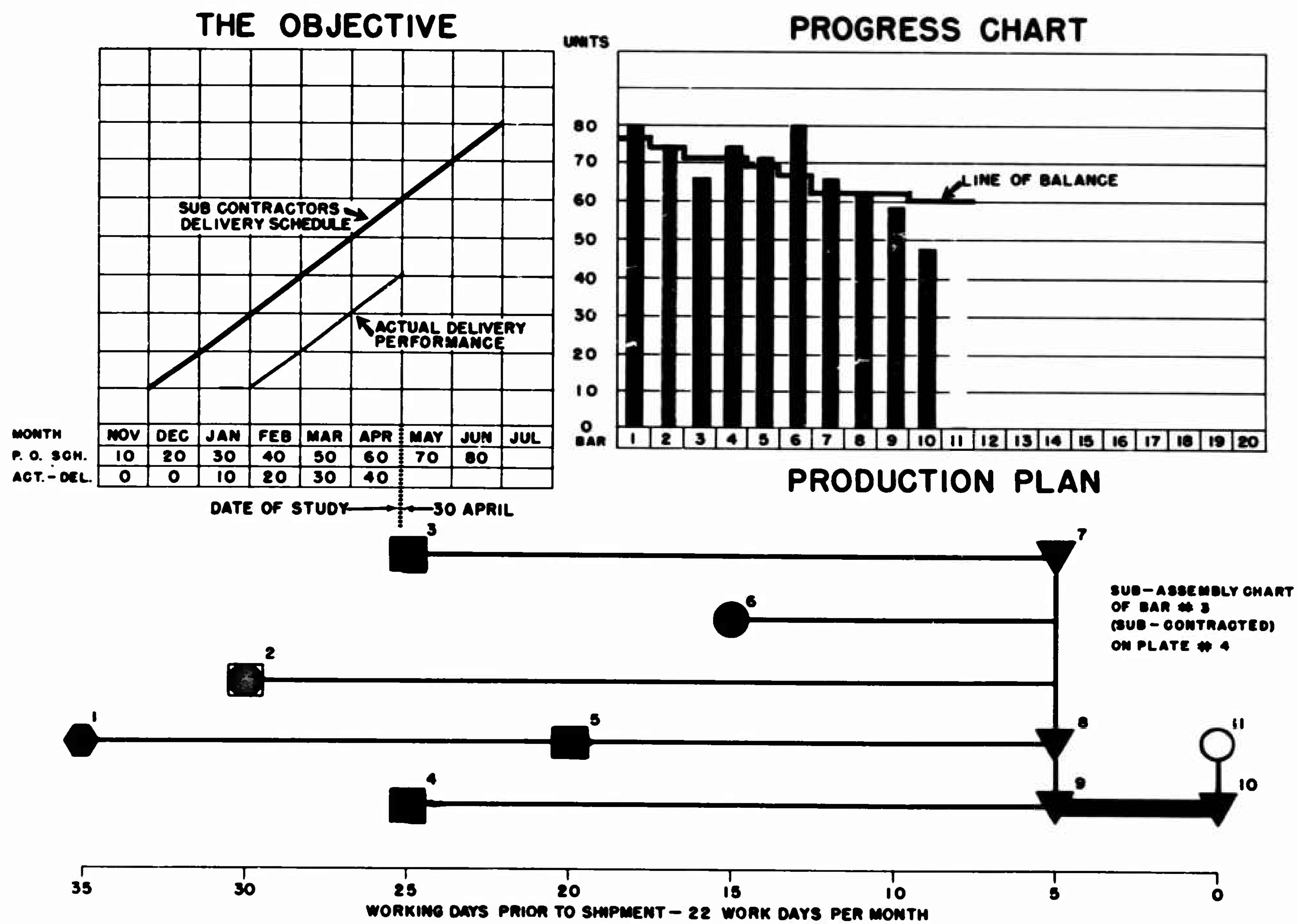

THE OBJECTIVE
SUB CONTRACTORS DELIVERY SCHEDULE
ACTUAL DELIVERY PERFORMANCE
MONTH NOV DEC JAN FEB MAR APR MAY JUN JUL
P. O. SCH. 10 20 30 40 50 60 70 80
ACT.-DEL. 0 0 10 20 30 40
DATE OF STUDY 30 APRIL
PROGRESS CHART
UNITS
80 70 60 50 40 30 20 10 0
BAR 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
LINE OF BALANCE
PRODUCTION PLAN
SUB-ASSEMBLY CHART OF BAR # 3 (SUB-CONTRACTED) ON PLATE # 4
1 2 3 4 5 6 7 8 9 10 11
35 30 25 20 15 10 5 0
WORKING DAYS PRIOR TO SHIPMENT - 22 WORK DAYS PER MONTH

PLATE NO. 5

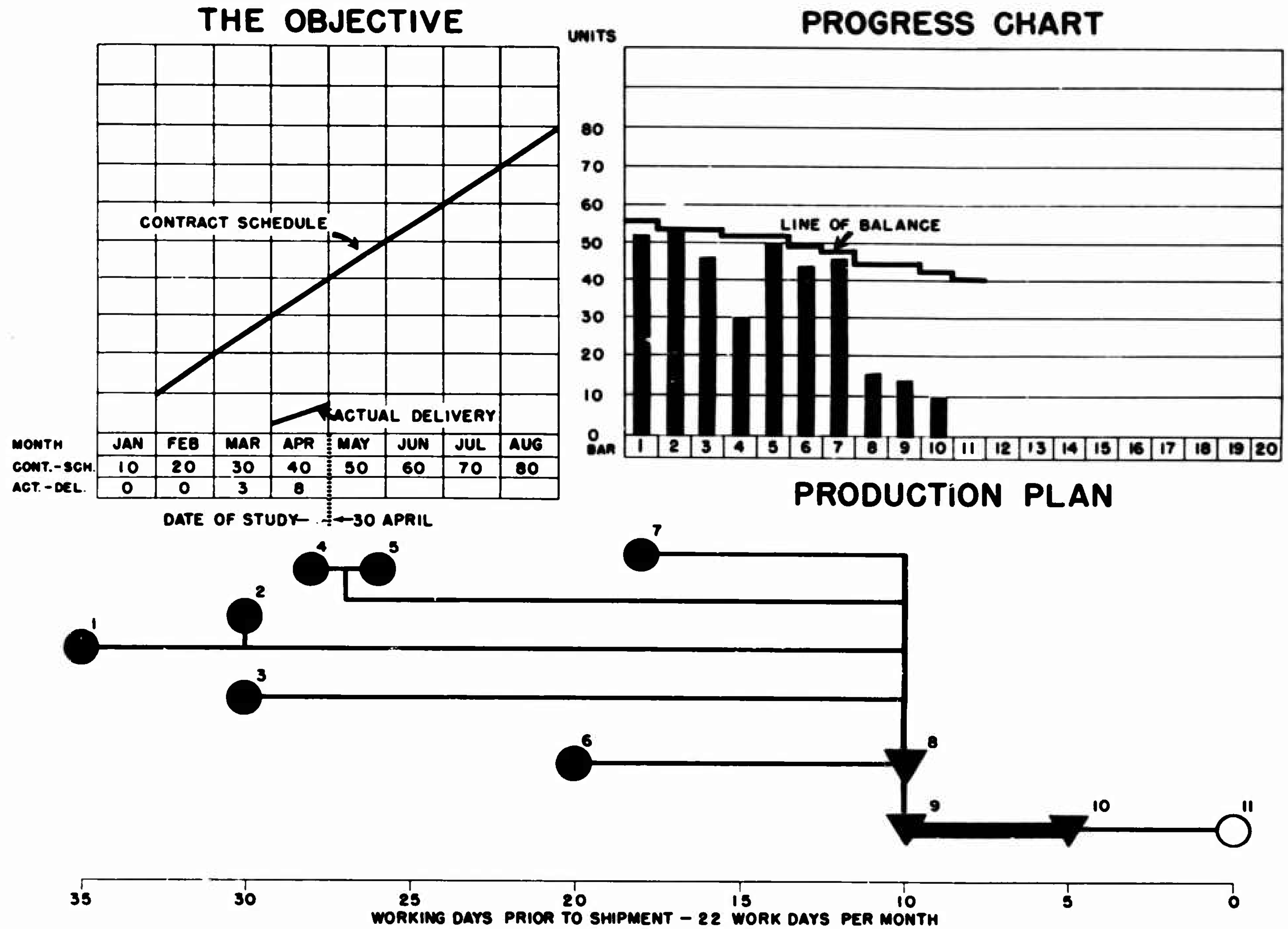

THE OBJECTIVE
CONTRACT SCHEDULE
ACTUAL DELIVERY
MONTH
CONT.-SCH.
ACT.-DEL.
JAN FEB MAR APR MAY JUN JUL AUG
10 20 30 40 50 60 70 80
0 0 3 8
DATE OF STUDY— —30 APRIL
PROGRESS CHART
UNITS
80 70 60 50 40 30 20 10 0
BAR
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
LINE OF BALANCE
PRODUCTION PLAN
1 2 3 4 5 6 7 8 9 10 11
35 30 25 20 15 10 5 0
WORKING DAYS PRIOR TO SHIPMENT – 22 WORK DAYS PER MONTH

PLATE NO. 6

Section V—Interpretation of Charts

The next step is the interpretation of the chart and evaluation of the production situation as depicted by the various elements of the chart. Some of the information which may be extracted is plainly obvious and can be expressed as simple fact. Other intelligence which may be derived is not necessarily quite so obvious, but is sometimes very fundamental. Some of the more common points to be noted in preparing an interpretation are:

IMBALANCES ON THE PROGRESS CHART:

The prime purpose in preparing a LOB chart has been explained to be to develop a comparison of current progress with planned objective; therefore, the paramount observation to be made is whether or not progress is in phase with the objective. The bars which are below the balance line are the elements of the endeavour which can be picked up by top management as requiring remedial action. A salient point to bear in mind is that shortages in the long lead time elements will automatically create shortages in dependent shorter lead time components. For example, on Plate 3 (Synchro) it is impossible for bar No. 35, the housing-stator assembly, to reach or exceed the balance line quantity until after bar No. 31, the start of assembly of the stator into the housing, reaches the balance quantity. In turn, it is impossible for bar No. 31 to reach or exceed the balance line quantity until bar No. 15, start of machining of housings, reaches the balance quantity. Another important point of observation is the noting of patterns of imbalances for various source types. For example, if receipt of purchased parts is far ahead of respective balance quantities, some stretch out in subsequent deliveries may prevent excessive tie-up of capital in inventory; also, if in-plant manufacturing is considerably behind, it is obvious that these two phases of the overall effort require synchronization.

INFORMATION FROM THE OBJECTIVE CHART:

Once deliveries have commenced, valuable information can be derived from a comparison of the actual delivery curve with the planned delivery curve. A comparison of the slopes of the two curves will indicate whether or not current lead or lag of deliveries may be expected to continue. Horizontal difference in the two curves indicates lead or lag in terms of time; whereas the vertical difference indicates lead or lag in terms of delivered units.

Section VI—Presentation of Results

In those cases where an outside group such as an Inspector of Naval Material conducts a study at a contractor's plant, a presentation should be made to top management, which will spell out the findings of the study and recommendations of the group. This presentation should be made in as formal a fashion as possible. It should be attended by top management, including all department heads. The information to be discussed should be organized carefully so that the presentation will be brief and to the point. An effort should be made to anticipate questions and to have answers ready.

The first general segment of the presentation should provide an interpretation as described earlier in this chapter. Remarks pertaining to individual problems may well be directed to the appropriate department head, if present.

The second general segment should comprise a discussion of possible remedial actions. This may involve improving the overall situation on an entire source type, such as accelerating all procurement or general speed-up of all plant operations. On the other hand, and more usually, it may involve improving progress on one or more segments of the overall process—changing processing methods, overtime, changing emphasis of attention, modifying the production plan (flow of materials), performing tests concurrently with production, expediting delivery of individual purchased materials and components, modifications of design or specifications, making additional production capacity available, hiring additional manpower—are only a few of the devices which can be suggested to accelerate progress.

The third segment of the presentation should cover the importance of periodic updating of the chart(s). The original chart provides a still picture indicating areas requiring actions,

whereas updated revisions provide a continuing picture of the production situation as it changes. Improvements or further slippages are easily noted. Also, revisions of lead times may be made on the production plans of the updated charts. Normally, such revisions are needed on a few particular elements. Additional deliveries are noted on the objective chart, stock status is annotated on bars of the progress chart and a new line of balance is constructed as of the date of the revision. Arrangements should be made as to updating so that it will be accomplished in orderly fashion.

It will be noted that for objectives which can be represented by a linear curve or an almost linear curve, each Line of Balance is exactly parallel and has the same configuration as every other one for that objective curve except in the event that the production plan is altered. Also, it will be noted that the height of the Line of Balance will be the same for all components having the same lead time. It is, therefore, sometimes convenient to make a template for plotting successive lines of balance. It will be noted that if the instructions previously given were used for numbering the points of the production plan, the Line of Balance would always descend from left to right.

If the study is internal within a private industrial concern or within a manufacturing activity of the Government, the foregoing presentation may be varied or dispensed with completely, as may be appropriate.

Part III

Special Applications of Line of Balance

Section I—General

As described previously, the Line of Balance (LOB) technique is basically a tool for exercising surveillance over production programs. The classic or pure application envisions repetitive fabrication of appreciable quantities (usually not less than a dozen) of an end item to meet a phased schedule.

However, there also exists an equal or even greater need for the ability to evaluate accomplishment, using a formal surveillance technique, for other types of industrial effort. LOB can be used to observe performance on many of these by judiciously modifying the mechanics of applying it. The resulting charts are easily analyzed and do reveal how well performance conforms to planned objectives. Problem areas are highlighted by the same means as in the production application.

Section II—Monitoring a Development Project (Prototype)

This section describes the application of LOB to a development project involving the manufacture of a single piece of equipment—a prototype or preproduction model. In the example (Plate 7), the basic time goal is to complete the project by the end of December 1961. The sequence of study and charting is as follows:

1. Develop and diagram the plan, breaking the project into phases.
2. Plot the objective diagram expressing the schedule for accomplishment of each phase as an individual, independent objective.
3. Determine and plot present progress.
4. Construct the LOB.

Note that the ordinates on the objective chart and the progress chart are in terms of percent completion.

The sample hypothetical chart shown on Plate 7 was constructed using the data tabulated in Tables 1 and 2. The diagram of the plan was constructed by resolving the project into phases and then denoting the start and finish of those various phases. The start of a phase was denoted by an open symbol; the completion by a similar symbol filled in. The time base on the plan was set up in terms of calendar dates, rather than lead time prior to completion. The number of months estimated to be required to accomplish the various phases was tabulated in Table 1 (1st column).

In order to construct the objective diagram, the schedules for the various phases of the project were lifted from the plan and plotted as straight lines on the objective chart. (If it had been known that the schedules were not linear, and if the curvature had been known, then the appropriate curves would have been used. However, experience indicates that linear schedules for the component phases normally are sufficiently accurate.) The schedules on the objective chart were keyed to the plan by number.

A composite planned schedule for the total project may be computed by assigning estimated man-hour values, or dollar values, or elapsed time values to each of the phases on the plan and then totaling them month by month. In this instance, elapsed time values (phase months) were used as a basis and were applied as follows:

The gross input for the project added up to 37 phase months (although the project covered a calendar period of 17 months); therefore, each one-month planned input on a phase was represented as 2.7% of the project ($100 \div 37 = 2.7\%$). Then at any time, the desired over-all accomplishment would be 2.7 times the total number of useful phase months input on the project so far. On this basis, the planned percentage of accomplishment for each of the 17 months became as shown in Table II. This data (Column 3 of Table II) was used to plot the over-all objective curve.

MANUFACTURE OF A TRANSCEIVER — PROTOTYPE

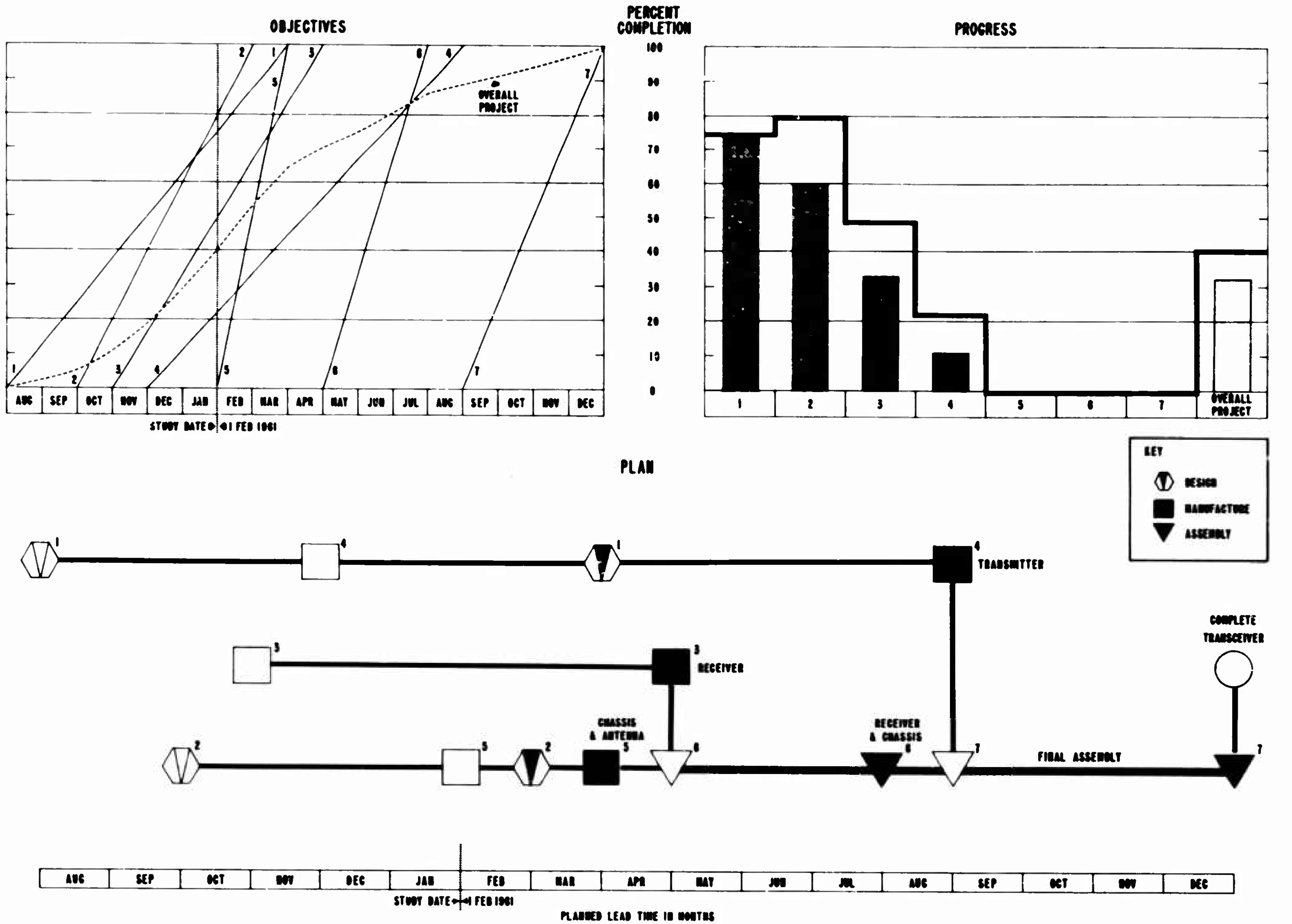


PLATE NO. 7

In constructing the Progress Chart, the percentage of completion for each phase was computed as follows:

Let a = number of months yet required to complete a particular phase. (This estimate must be based upon predetermined intermediate milestones.)

And A = gross number of months originally estimated for the entire phase.

Then at any time:

$$\% \text{ completion} = 100\left(1 - \frac{a}{A}\right)$$

The above percent completion method is prescribed rather than the more obvious procedure of setting the number of months completed over the gross number of months originally estimated for the entire phase. While the prescribed method requires one additional mathematical step, it helps compensate for inaccuracies in the initial estimate of time required for the entire phase.

The percentage of completion of the over-all project was computed as follows:

Let b = the number of phase months yet required to complete the phases of the project (utilizing a base of predetermined intermediate milestones as indicated above).

And B = gross number of phase months input originally estimated for the entire project.

Then at any time:

$$\% \text{ completion} = 100\left(1 - \frac{b}{B}\right)$$

The percent completion for phases 1, 2, 3 and 4, was, then: (data from Table I)

Phase 1: $100\,(1 - 2/8) = 75$ percent
Phase 2: $100\,(1 - 2/5) = 60$ percent
Phase 3: $100\,(1 - 4/6) = 33$ percent
Phase 4: $100\,(1 - 8/9) = 11$ percent

The percent completion for the over-all project was then:

$$100\,(1 - 25/37) = 32 \text{ percent}$$

The Line of Balance was constructed as follows:

a. On the Objective Chart, a vertical line was drawn at the study date (1 February 1961).

b. The Balance level for each phase was the intercept on the objective chart of its individual schedule with the vertical line. This, in turn, was projected horizontally to the corresponding bar on the progress chart. The individual balance levels were connected to form a Line of Balance.

Note that in this type of application, the balance line will not necessarily be a continuing descending line from left to right. Also note that if the schedule for a particular phase is not intercepted by a vertically projected line at the study date, the balance level for that phase must then either be 0% or 100%, for in such case the phase will have been scheduled to have been completed or not yet started.

Table I

	Phase No.	(1) Total estimated input months	(2) Estimated months required yet to complete [1]	(3) Estimated percent completed on 1 Feb.
Design of transmitter	1	8	2	75
Design of chassis and antenna	2	5	2	60
Manufacture receiver	3	6	4	33
Manufacture transmitter	4	9	8	11
Manufacture chassis and antenna	5	2	2	0
Assemble receiver and chassis	6	3	3	0
Final assembly	7	4	4	0
OVER-ALL TRANSCEIVER	. . .	37	25	32

[1] These estimates are as of the time of updating and are independent of the original estimates for the entire phases.

Table II

End of	(1) Phase months operating during month	(2) Cumulative total phase months to date	(3) Planned percent completion in terms of phase months
August	1	1	2.7
September	1	2	5.4
October	2	4	10.8
November	3	7	18.9
December	4	11	29.7
January	4	15	40.5
February	5	20	54.0
March	4	24	64.8
April	2	26	70.2
May	2	28	75.6
June	2	30	81.0
July	2	32	86.4
August	1	33	89.1
September	1	34	91.8
October	1	35	94.5
November	1	36	97.2
December	1	37	99.9

Section III—Analyzing Over-all Plant Operation

In many instances it becomes useful to analyze what is taking place in various segments of an industrial complex and to observe improvements or deterioration of operations. Plate 8 treats the programming at a plant which is working on 4 projects: A, B, C and D. The schedule for accomplishing the various functions on these projects is as shown in Table III. Again, as in the preceding section, the common denominator for computations is phase-months based upon predetermined milestones. The methodology for this type application is similar to that used in the preceding section; accordingly, a description of the details of computation will not be repeated.

The basic objective becomes the completion of the various projects on which the plant is engaged. The phases become defined as work which must be accomplished by various departments on the individual projects.

Additional data for Plate 8 is provided in Tables IV and V. Table IV contains the following data:

(a) Columns 1, 3, 5, and 7 contain the estimates, made at the start of the project, of the number of months that would be required to accomplish each phase of each project.

(b) Columns 2, 4, 6, and 8 contain estimates, made on 1 February, of the number of months of input yet required to complete each phase of each project.

Planned total percent completion for each function (all four projects) is tabulated by months in Table V. These percentages are based upon the data provided in columns 1, 3, 5, and 7 of table IV. Calculation of the over-all completion (planned), by months, is made by the method described in Section II. The results are tabulated in column 5 of Table V.

Computation of actual percentages of completion as of 1 February is as follows:

Engineering: $100\,(1-3/9)=67$ percent

Procurement: $100\,(1-11/20)=45$ percent

Fabrication: $100\,(1-17/18)=6$ percent

Over-all: $100=100\,(1-37/53)=30$ percent

Numbering of the phases or tasks on this chart is not essential because progress is not measured in terms of accomplishment achieved on each individual phase.

In this case there have been delays in engineering which have already hampered the procurement efforts and caused the over-all lag. At this point, it would appear that the following steps might be appropriate:

PROD the Engineering Department

USE overtime on the remaining engineering tasks

EXPEDITE delivery of purchased parts

ALERT manufacturing departments to be ready for speed-up of fabrication, assembly, and test.

However, the important conclusion is that management should take steps to strengthen the Engineering Department so that it can handle a greater workload and stay in phase with the other departments on future programs.

Table III

Function	Project A	Project B	Project C	Project D
Start engineering	1 OCT 60	1 SEP 60	....	1 JAN 61
Finish engineering	30 NOV 60	31 DEC 60	....	31 MAR 61
Start procurement	1 NOV 60	1 NOV 60	1 AUG 60	1 APR 61
Finish procurement	28 FEB 61	31 MAR 61	31 MAR 61	30 JUN 61
Start fabrication	1 MAR 61	1 FEB 61	1 JAN 61	1 JUN 61
Finish fabrication	31 AUG 61	30 APR 61	31 MAY 61	30 SEP 61
Start assembly	1 SEPT 61	1 MAY 61	1 JUN 61	1 OCT 61
Finish assembly	31 OCT 61	31 MAY 61	30 JUN 61	30 NOV 61

Table IV

Project	Engineering months		Purchasing months		Fabrication months		Assembly and test months	
	Total input (1)	Yet to go (2)	Total input (3)	Yet to go (4)	Total input (5)	Yet to go (6)	Total Input (7)	Yet to go (8)
A	2	0	4	2	6	6	2	2
B	4	1	5	3	3	3	1	1
C	0	0	8	3	5	4	1	1
D	3	2	3	3	4	4	2	2
Total	9	3	20	11	18	17	6	6

Table V

End of month	Percent completion engineering (1)	Percent completion Purchasing (2)	Percent completion fabrication (3)	Percent completion assembly & test (4)	Percent completion over-all (5)
August	....	5	....	....	2
September	11	10	....	....	6
October	33	15	....	....	11
November	55	30	....	....	21
December	66	45		....	28
January	77	60	6	....	38
February	88	75	17	....	49
March	100	85	33	....	60
April	....	90	50	....	68
May	....	95	61	17	76
June	....	100	72	33	83
July	....	....	83	33	87
August	....	....	94	33	91
September	....	....	100	50	94
October	....	....	....	84	98
November	....	....	....	100	100

Section IV—Monitoring Expenditures

The Line of Balance technique can also be used to monitor expenditure of funds on a program. This is an application which can be a very vital factor in exercising close financial surveillance. By comparing actual expenditures against those originally planned and by observing corresponding progress or physical accomplishment, close control can be exerted on the rate of making expenditures, thereby, large cost overruns can be avoided. Studies and charts of this nature can be used at several levels of management to monitor expenditures by the various departments.

There are several ways of incorporating "dollars" into Line of Balance charting. Two of these are shown here as applied to production programs. Similar ideas may be incorporated into charts pertaining to development programs.

On Plate 9, a production type Line of Balance chart has been augmented by superimposing cost information. In this instance, cost information was developed on a basis of a functional analysis of expenditures, i.e., engineering, tooling, material, fabrication, assembly, etc.

The basic Objective, Program, Program Progress,

MULTI-PROJECT SURVEILLANCE

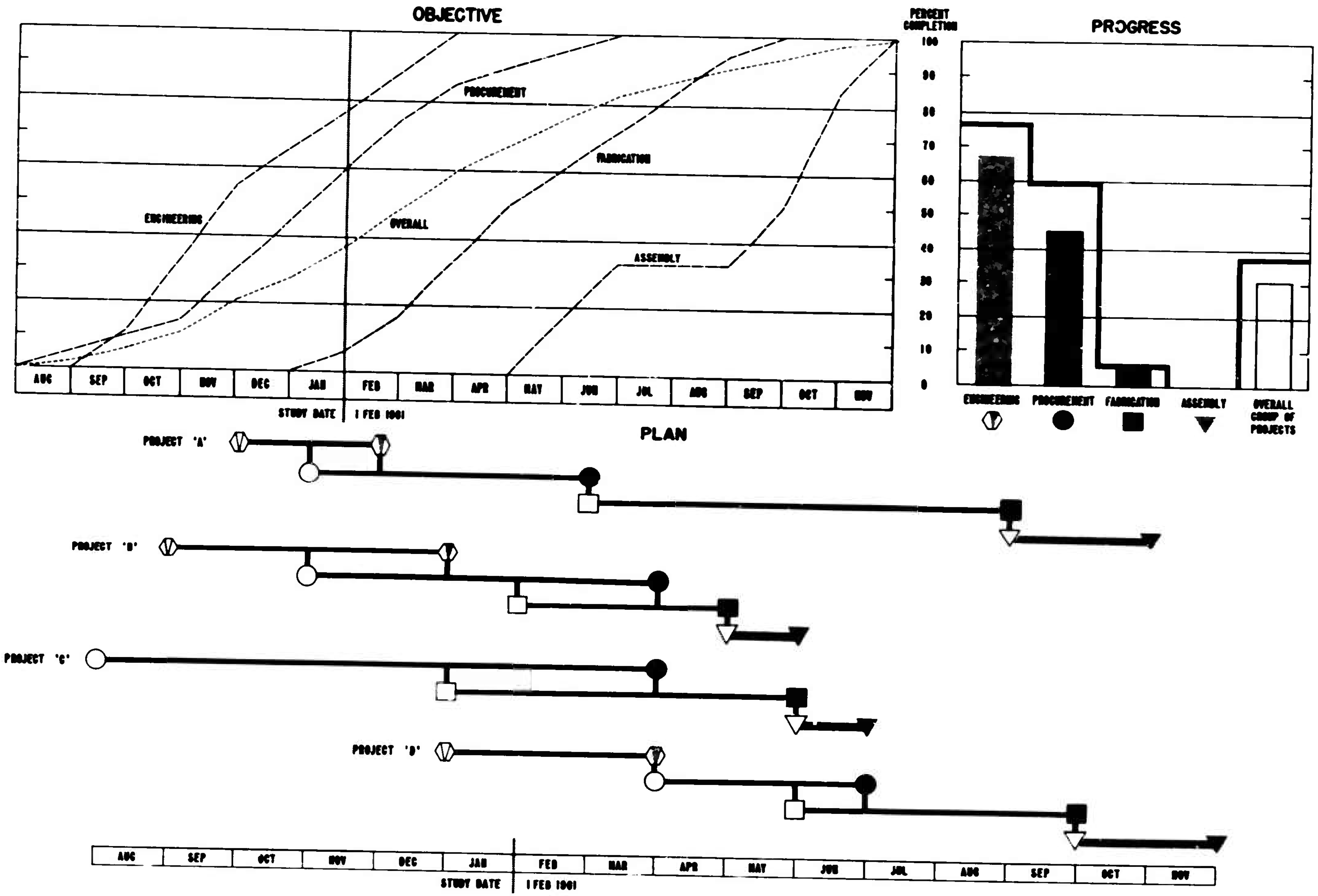
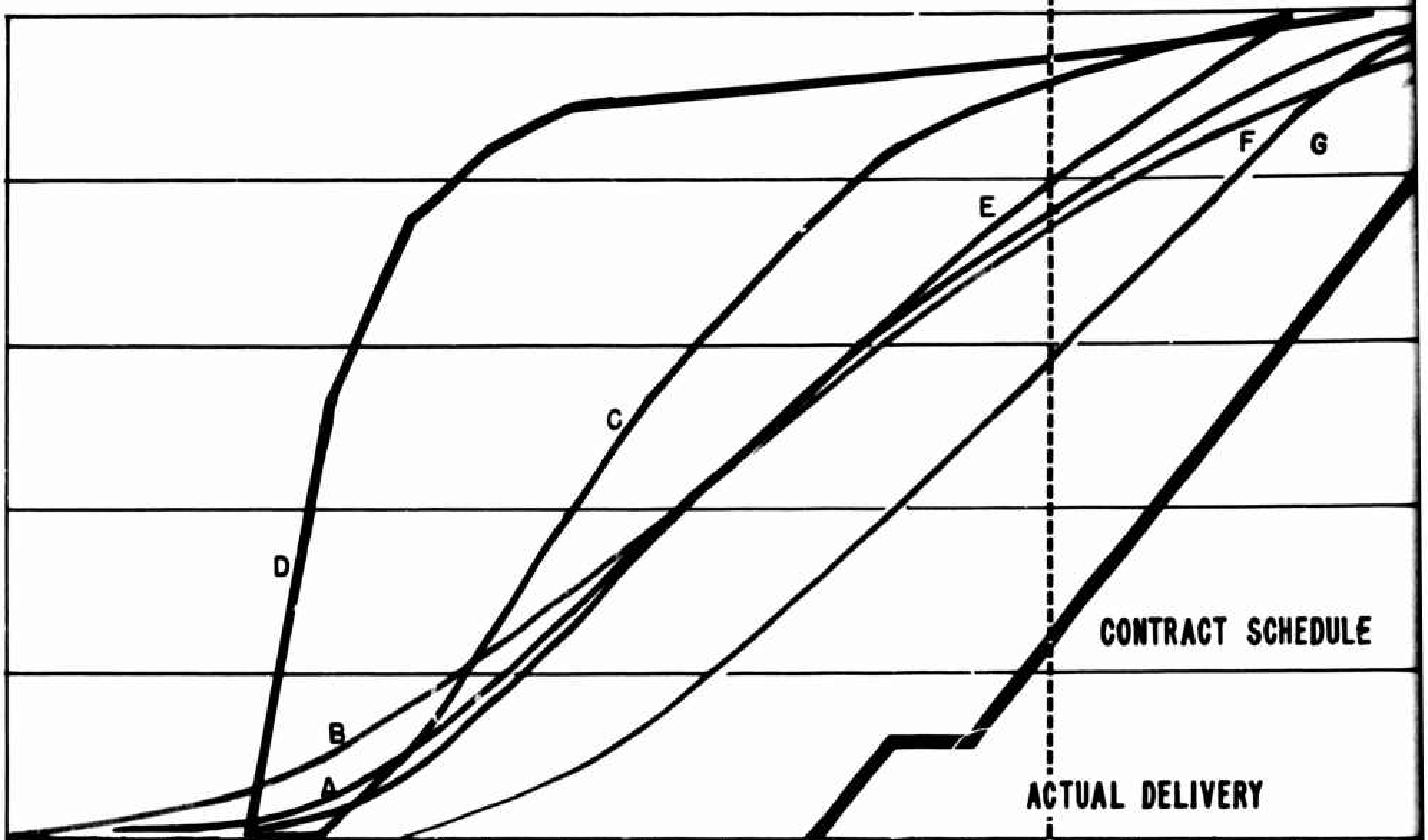


PLATE NO. 8

SURVEILLAN[illegible]

PROGRAM OBJECTIVE (CUMULATIVE)



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	J[illegible]
CONTRACT SCHEDULE										2	2	4	6	8	10	12	1[illegible]
ACTUAL DELIVERY											1	2					

1960 STUDY DATE ➧ ➧ 1 FEB 1961

PROGRAM EXPENDITURES

INPUT $

A	2.3M	6.0	11.3	95.6	236.3	452.2	682.[illegible]	[illegible]	[illegible]	[illegible]0	1373.7	1576.0	1751.4	1911.9	2064.2	2213.0	2348.6	2441.1	248[illegible]
	.1	.2	.5	3.8	9.5	18.1	27.3	3[illegible]	[illegible]	[illegible]5.0	63.0	70.0	76.4	82.5	88.5	93.9	97.6	99.[illegible]

PERCENT %

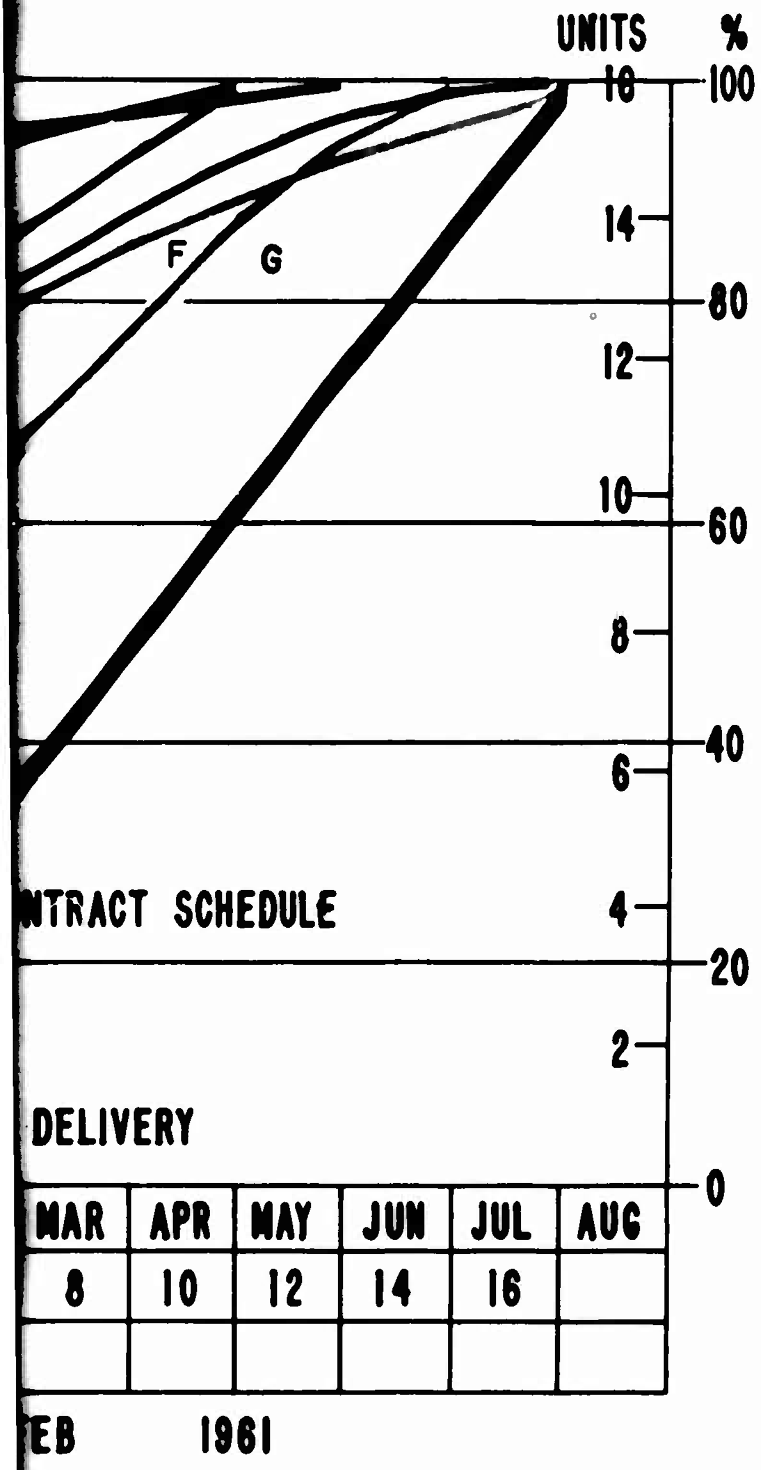
A

B	2.3	6.0	11.3	19.3	31.5	44.4	58.6	73.6	88.6	104.4	118.4	133.8	146.5	157.8	168.5	176.5	184.1	18[illegible]
	1.2	3.1	5.8	9.9	16.2	22.8	30.1	37.8	45.5	53.6	61.3	68.7	75.2	81.0	86.5	90.6	94.5	97.[illegible]

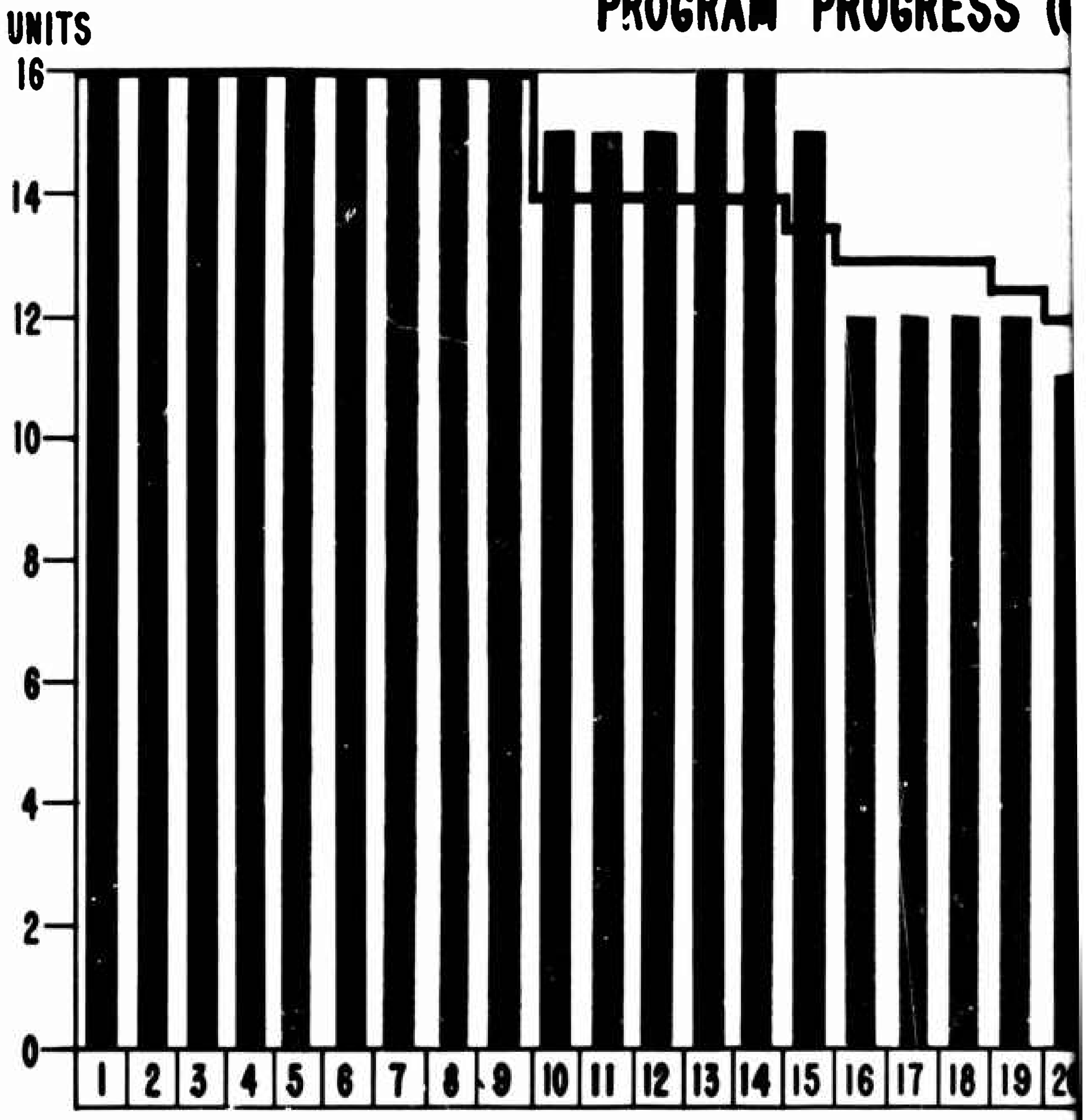
C	7.0	87.2	211.0	344.0	471.0	560.6	655.6	730.6	774.2	803.0	829.1	852.6	871.8	893.5	90[illegible]
	.8	10.0	24.2	39.5	54.0	64.3	75.2	83.8	88.8	92.1	95.1	97.8	100	102.5	103.[illegible]

80.2 85.6 95.4 101.2 102.3 103.5 104.6 105.8 106.9 108.0 109.[illegible] [illegible]

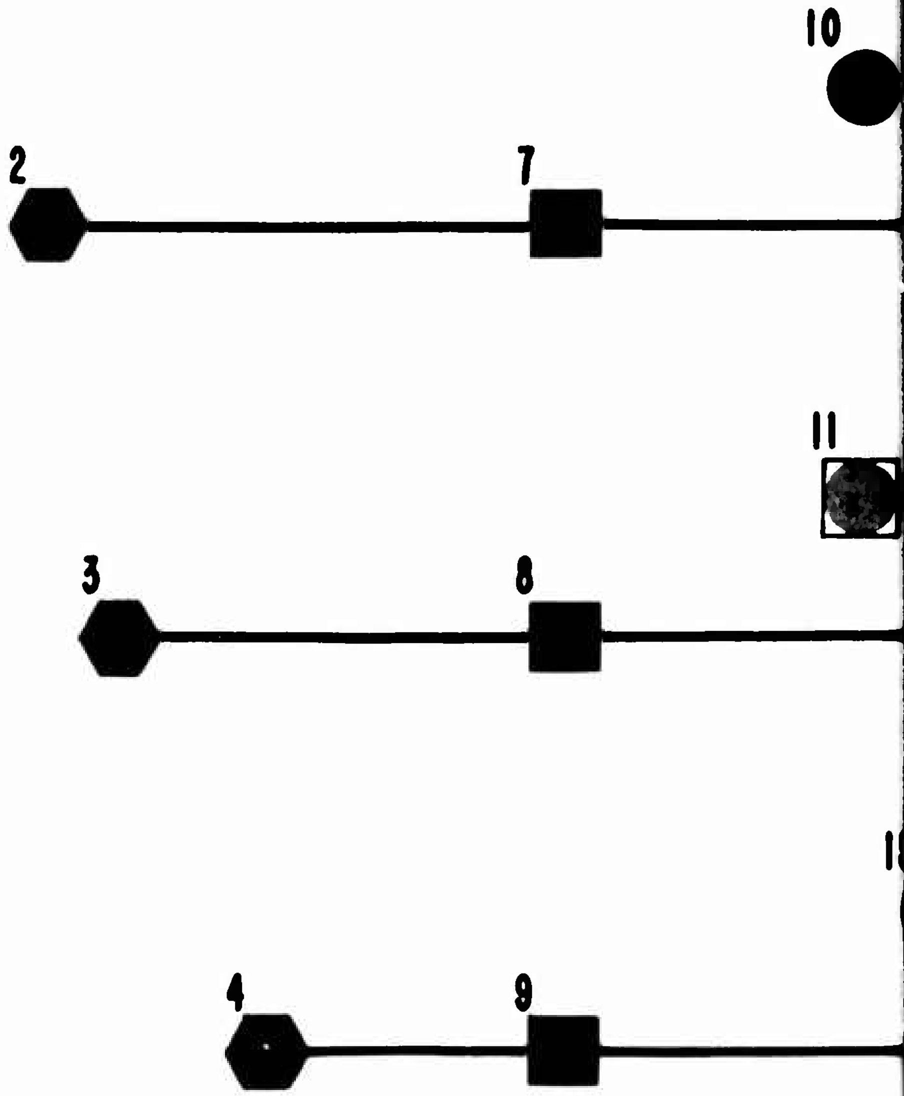
VEILLANCE OF PRODUCTION AND EXPENDITU



PROGRAM PROGRESS (



PRODUCTION P



2213.0 2348.6 2441.1 2488.3 2501.2

88.5 93.9 97.6 99.5 100

COMPOSITE

B

168.5 176.5 184.1 189.7 194.8

86.5 90.6 94.5 97.4 100

ENGINEERING

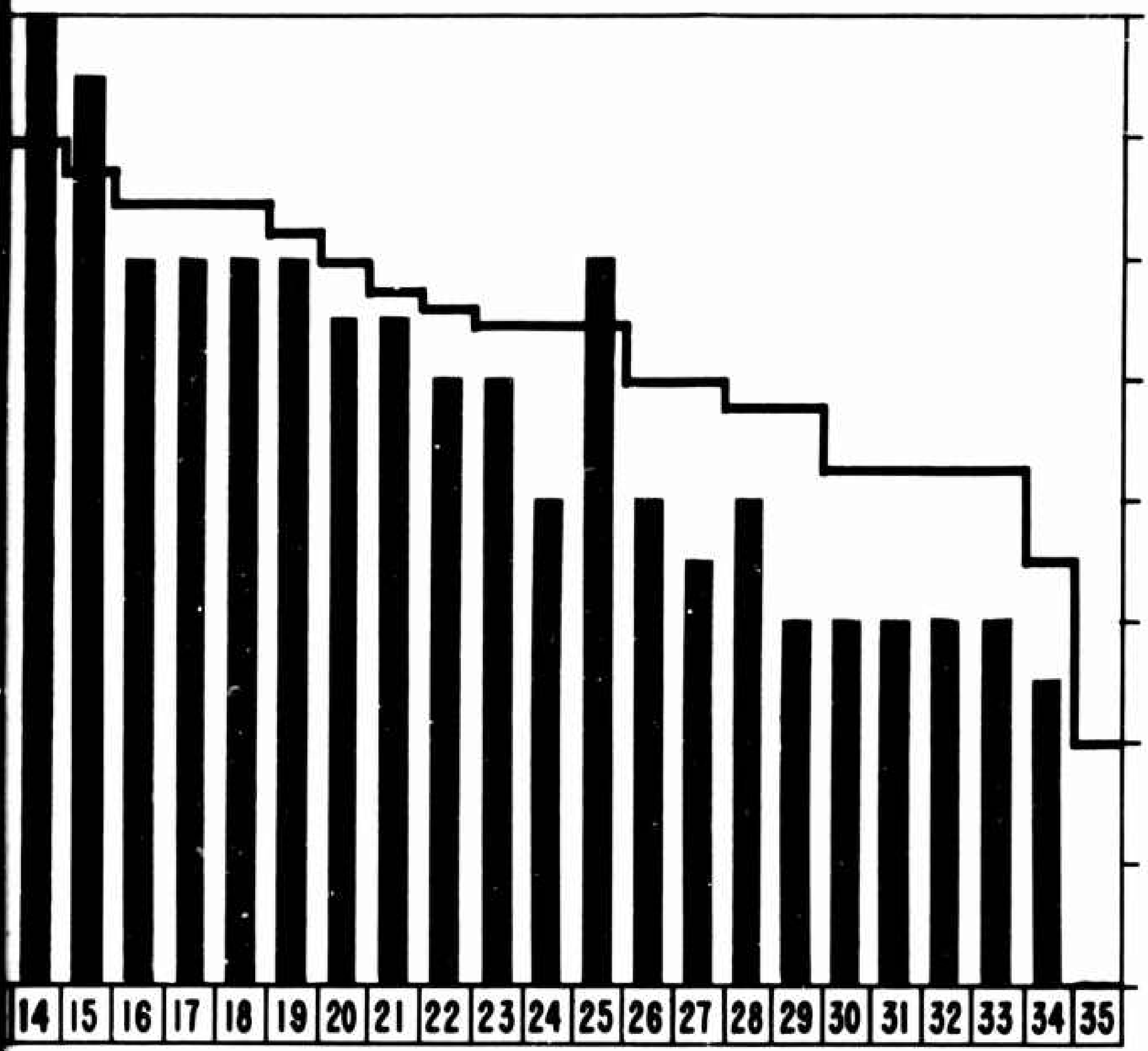
852.6 871.8 893.5 905.1

97.8 100 102.5 103.8

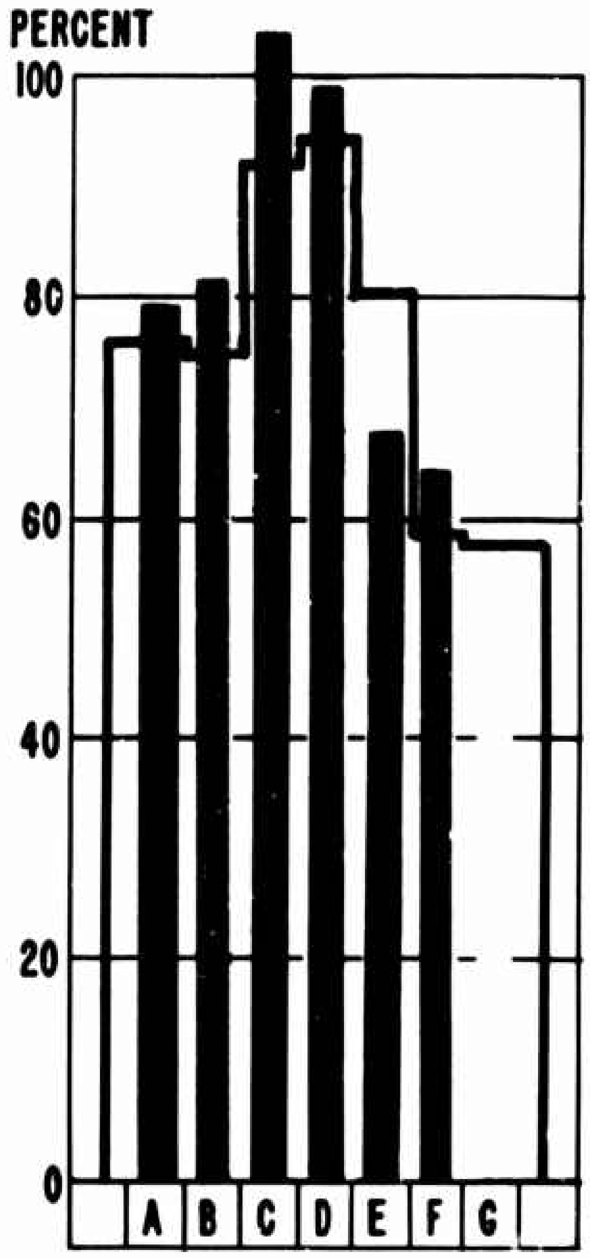
MATERIAL

XPENDITURES

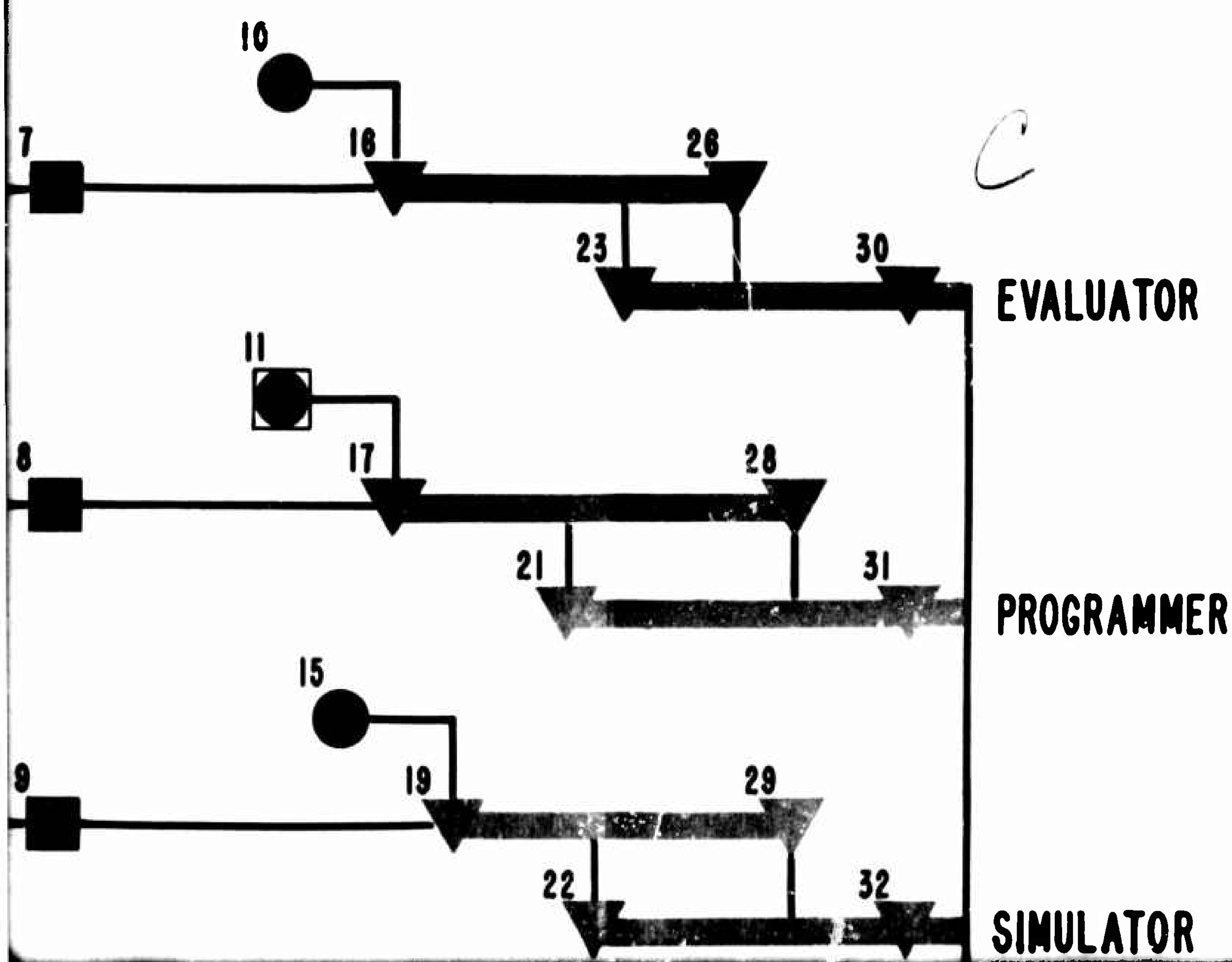
AM PROGRESS (CUMULATIVE)



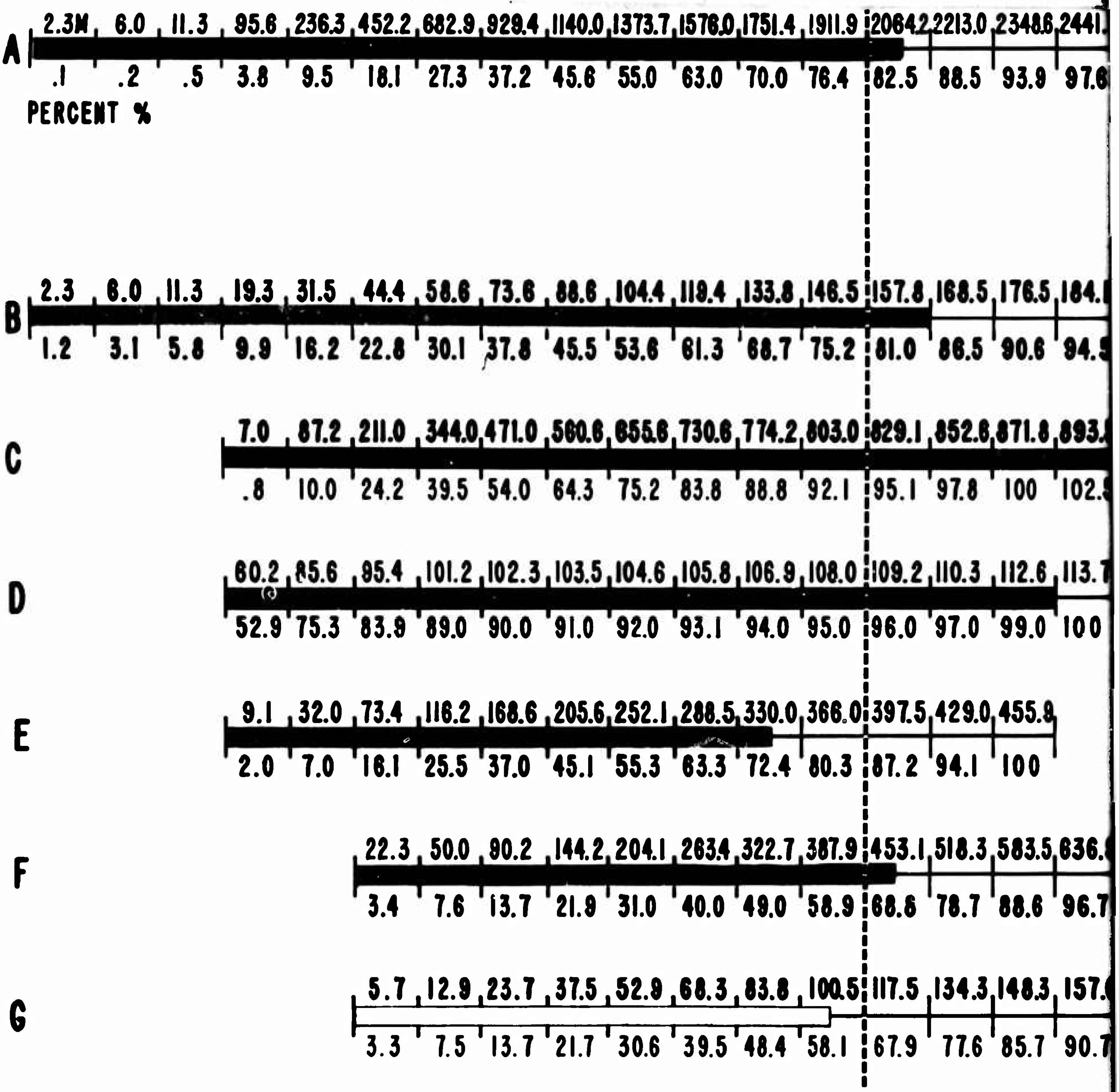
EXPENDITURES

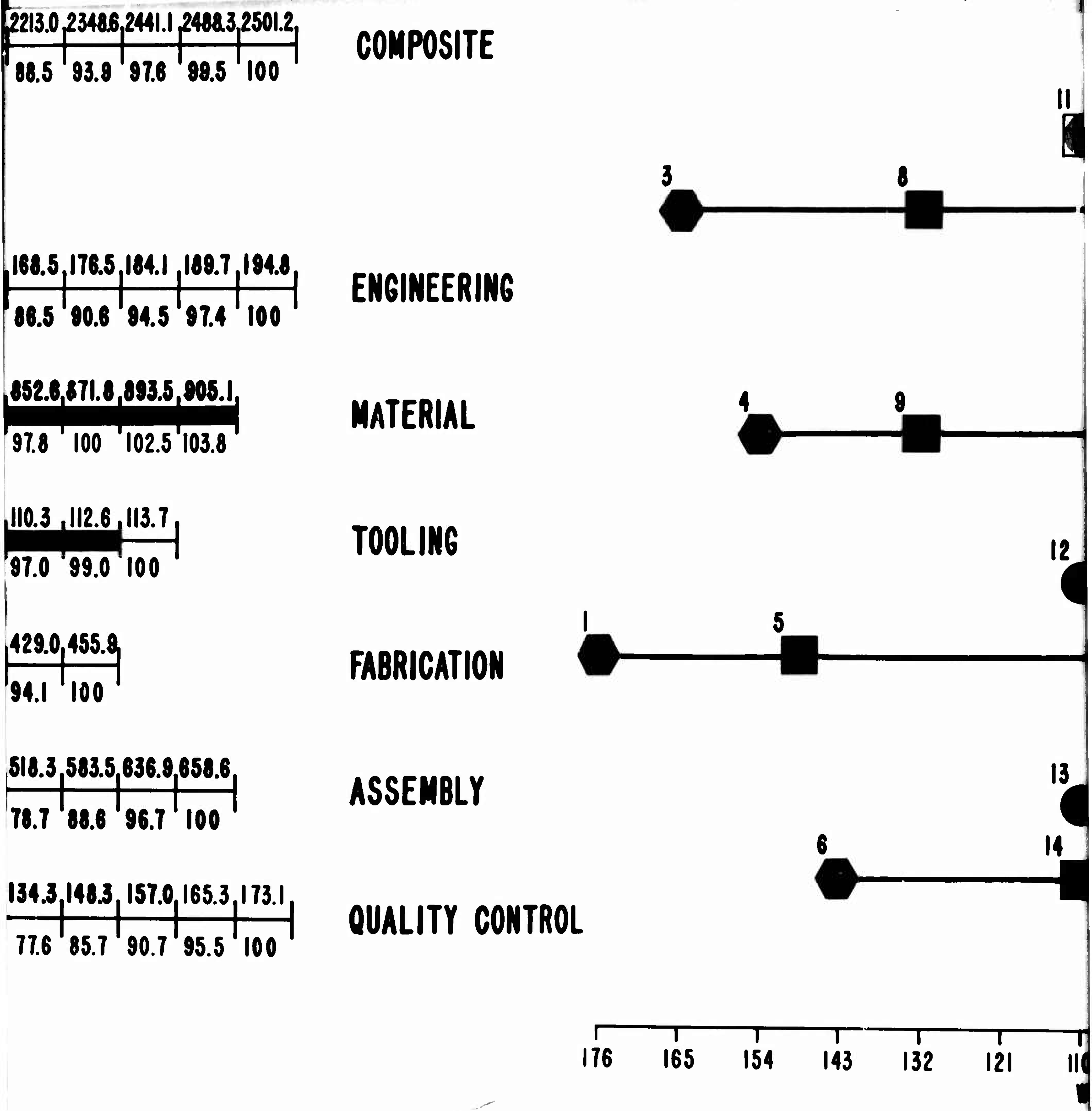


PRODUCTION PLAN

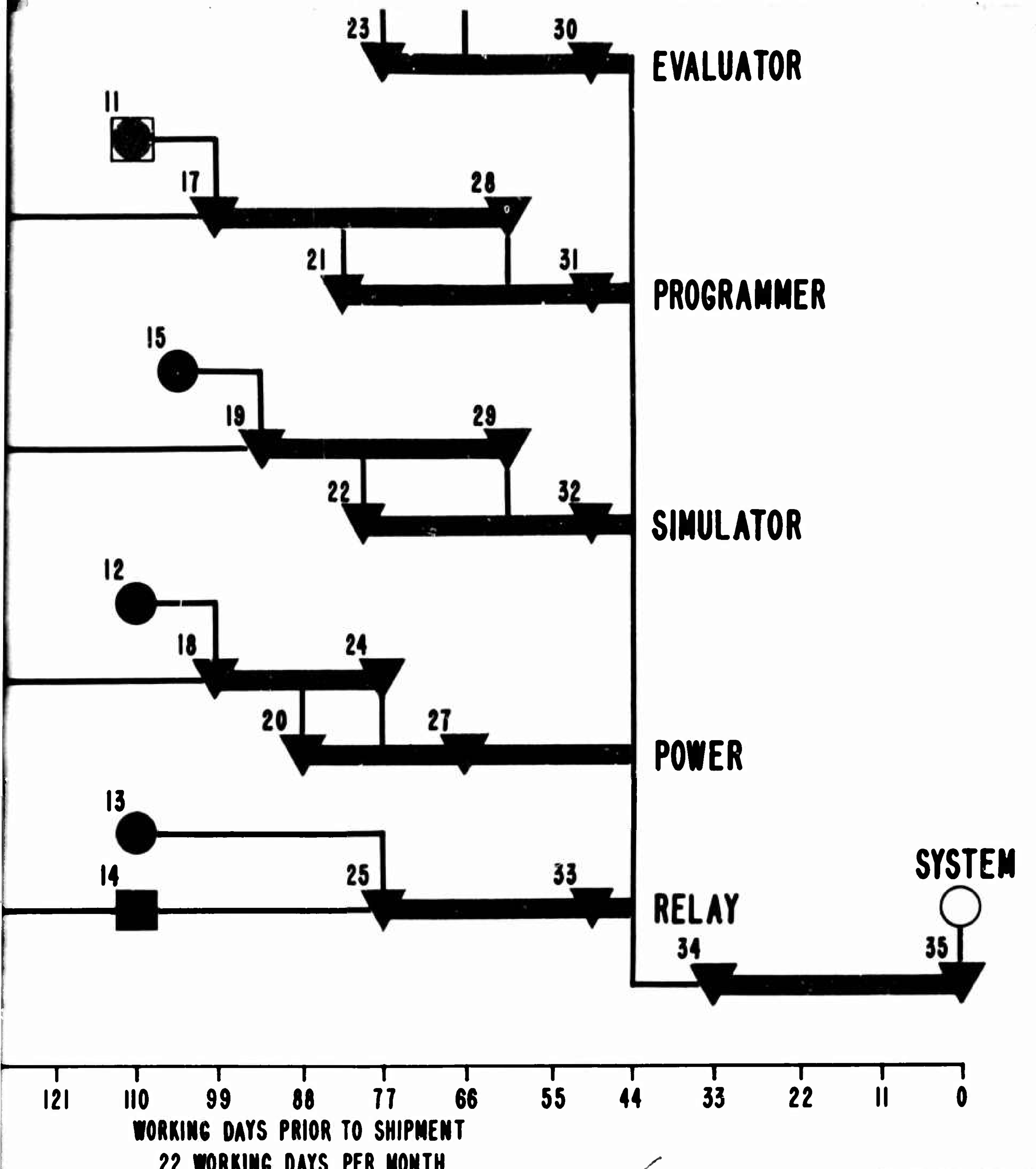


C


A
2.3M 6.0 11.3 95.6 236.3 452.2 682.9 929.4 1140.0 1373.7 1576.0 1751.4 1911.9 2064.2 2213.0 2348.6 2441.
.1 .2 .5 3.8 9.5 18.1 27.3 37.2 45.6 55.0 63.0 70.0 76.4 82.5 88.5 93.9 97.6
PERCENT %
B
2.3 6.0 11.3 19.3 31.5 44.4 58.6 73.6 88.6 104.4 119.4 133.8 146.5 157.8 168.5 176.5 184.
1.2 3.1 5.8 9.9 16.2 22.8 30.1 37.8 45.5 53.6 61.3 68.7 75.2 81.0 86.5 90.6 94.5
C
7.0 87.2 211.0 344.0 471.0 560.6 655.6 730.6 774.2 803.0 829.1 852.6 871.8 893.
.8 10.0 24.2 39.5 54.0 64.3 75.2 83.8 88.8 92.1 95.1 97.8 100 102.5
D
60.2 85.6 95.4 101.2 102.3 103.5 104.6 105.8 106.9 108.0 109.2 110.3 112.6 113.7
52.9 75.3 83.9 89.0 90.0 91.0 92.0 93.1 94.0 95.0 96.0 97.0 99.0 100
E
9.1 32.0 73.4 116.2 168.6 205.6 252.1 288.5 330.0 366.0 397.5 429.0 455.9
2.0 7.0 16.1 25.5 37.0 45.1 55.3 63.3 72.4 80.3 87.2 94.1 100
F
22.3 50.0 90.2 144.2 204.1 263.4 322.7 387.9 453.1 518.3 583.5 636.
3.4 7.6 13.7 21.9 31.0 40.0 49.0 58.9 68.6 78.7 88.6 96.7
G
5.7 12.9 23.7 37.5 52.9 68.3 83.8 100.5 117.5 134.3 148.3 157.
3.3 7.5 13.7 21.7 30.6 39.5 48.4 58.1 67.9 77.6 85.7 90.7



2213.0 2348.6 2441.1 2488.3 2501.2
88.5 93.9 97.6 99.5 100
COMPOSITE
168.5 176.5 184.1 189.7 194.8
86.5 90.6 94.5 97.4 100
ENGINEERING
852.6 871.8 893.5 905.1
97.8 100 102.5 103.8
MATERIAL
110.3 112.6 113.7
97.0 99.0 100
TOOLING
429.0 455.9
94.1 100
FABRICATION
518.3 583.5 636.9 658.6
78.7 88.6 96.7 100
ASSEMBLY
134.3 148.3 157.0 165.3 173.1
77.6 85.7 90.7 95.5 100
QUALITY CONTROL
11
3
8
4
9
12
1
5
13
6
14
176 165 154 143 132 121


23
30
EVALUATOR
11
17
28
21
31
PROGRAMMER
15
19
29
22
32
SIMULATOR
12
18
24
20
27
POWER
13
14
25
33
RELAY
SYSTEM
34
35
121
110
99
88
77
66
55
44
33
22
11
0
WORKING DAYS PRIOR TO SHIPMENT
22 WORKING DAYS PER MONTH

F

PLATE NO. 9

and LOB pertaining to physical accomplishment were constructed in accordance with the procedures described in Part I. Next, a compilation was developed of planned expenditures for each functional element of the program. This was then plotted underneath the Objective Diagram, using the time scale of the Objective, and employing a "time line" for each category of expenditure.

The actual makeup of this diagram is as follows:

(a) For each category of planned expenditure, the planned monthly dollar input is shown above its time line expressed cumulatively from the inception of the program; the corresponding percentage of planned expenditure is expressed below the time line.

(b) Actual expenditures, as they occur, are extended along the time line.

(Note: As evidenced on time line "C," Material, whenever actual expenditures for a category exceed the total planned for that category, annotation of the overage is made on the time line by recording the amount and the corresponding percentage.)

The expenditure schedules were then added to the Objective Diagram as a group of curves, expressed as planned cumulative percentages of expenditure per function.

A separate progress chart for expenditures was prepared by computing the percentage of the total planned spending already accomplished for each functional element. In order that these could be compared with the plan for spending, a LOB for expenditures was constructed using the intercept method described in Part III, Section II.

In the case of the chart shown as Plate 10, a production type LOB chart has been augmented by superimposing cost information. However, in this illustration, items of cost are directly identified with particular steps of the program as described on the plan. On the chart captioned "Expenditures," the bars represent actual cumulative total expenditures to date incurred for their individual corresponding control points. The level of these bars is expressed as a percentage of total planned expenditures for each control point. Overhead may be included or excluded purely by choice. However, the exclusion or inclusion must be consistent throughout. The balance level for each bar on the expenditure chart is constructed by horizontally extending the actual level of the corresponding bar on the progress chart. The concept here is that the expenditure of money to date, on any particular step of the program should be commensurate with actual accomplishment.

SURVEILLANCE OF PRODUCTION AND EXPENDITURES

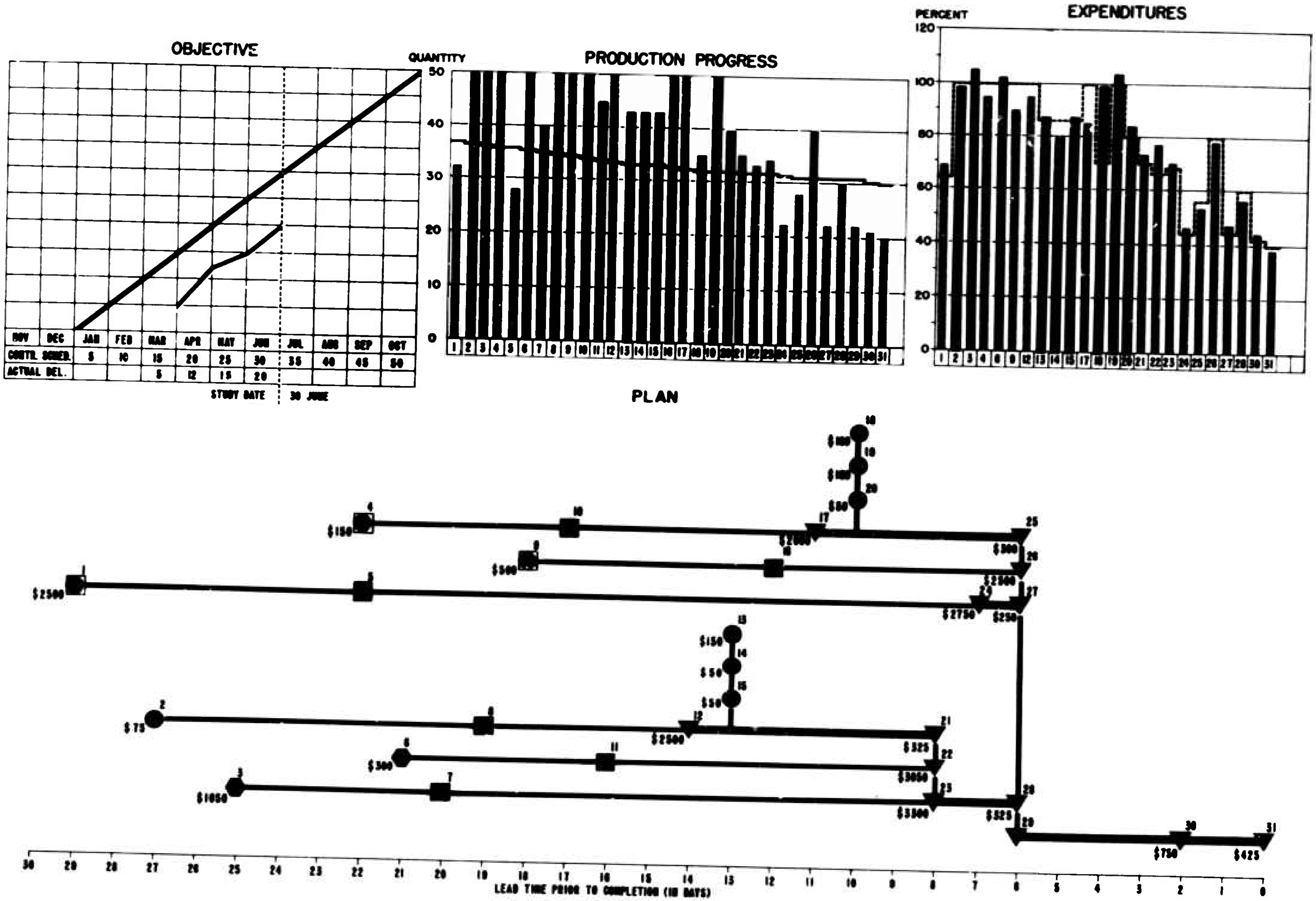


PLATE NO. 10

Appendix

Section I—Alternate Analytical Method

There is a mathematical alternate to the graphical method for arriving at the balance quantity for each control point. This analytical method involves the use of the general equation for a straight line, $Y_2 = Y_1 + M(X_2 - X_1)$, where X_1Y_1 and X_2Y_2 are coordinates of two points on the line and where M is the slope. In applying this equation for the above purpose, the terms of the equation have the following meaning:

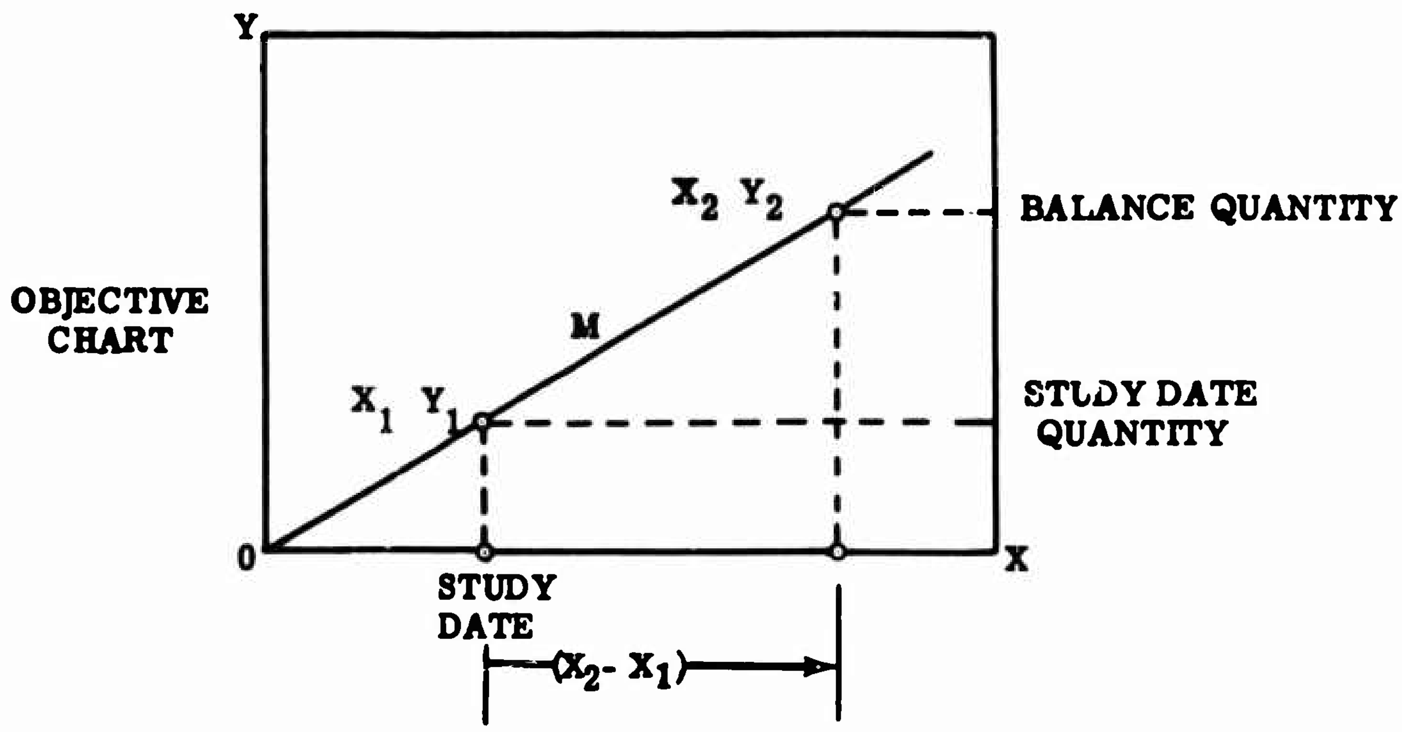
Y_2 = balance quantity for the control point (unknown)

Y_1 = number of end items due as of balance line date. This is read from the objective chart

M = scheduled delivery rate. This is derived from the objective chart

$(X_2 - X_1)$ = lead time for the control point. This is read from the production plan

The units used must be consistent throughout.



As examples, calculation of the balance quantity as of 1 May for control points 1, 3, and 6 on plate 6 is shown below:

$$Y_2 = Y_1 + M(X_2 - X_1)$$

$$Y_1 = 40 \text{ for each}$$

$$M = 10 \text{ for each}$$

Control Point 1	*Control Point 3*	*Control Point 6*
$X_2 - X_1 = \frac{35}{22}$	$X_2 - X_1 = \frac{30}{22}$	$X_2 - X_1 = \frac{20}{22}$
$Y_2 = 40 + 10 \times \frac{35}{22}$	$Y_2 = 40 + 10 \times \frac{30}{22}$	$Y_2 = 40 + 10 \times \frac{20}{22}$
$Y_2 = 55.9$ or 56	$Y_2 = 53.6$ or 54	$Y_2 = 49.1$ or 49

If the delivery schedule is slightly curved rather than a straight line, an average slope or delivery rate must be used. In the infrequent instances where the schedule is represented by a sharply curved line resembling a parabola or hyperbola, the equation for the locus of points on that type curve must be used instead of the straight line equation.

This alternate analytical method is particularly useful in those cases where periodic shortage lists for deficient items are to be published and circulated to the interested parties at frequent intervals.

Section II—Validity of the Balance Line

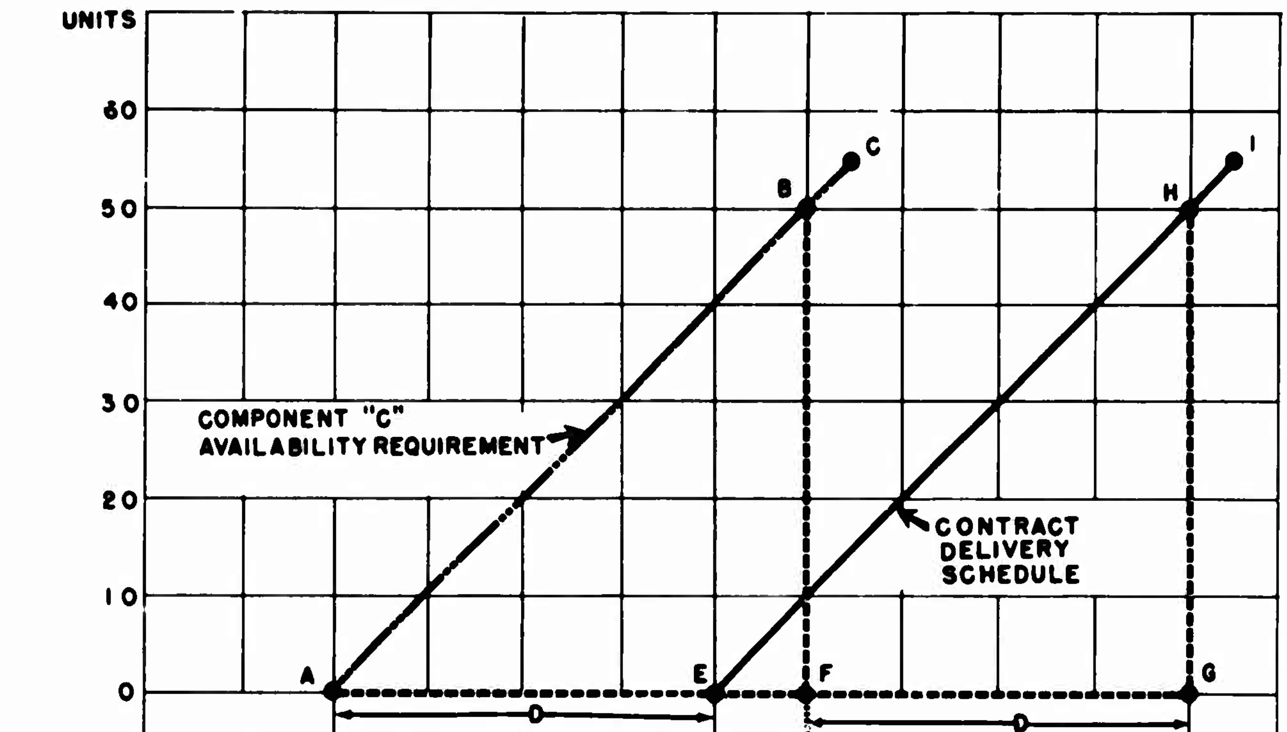
The validity of the graphical method for striking the balance quantity for each control point is based upon the following geometric proposition: (See Plate No. A)

1. Plot a general production plan and also an objective curve (Line EI).
2. Plot the schedule of required availability for a selected component C, having a lead time of D days.
3. Establish a study date (point F) and measure D days to right of point F and designate as point G. Construct verticals FB and GH.
4. *FB* is the required availability for component *C* as of the study date. *GH* is the LOB quantity for component *C* as of the study date. Therefore proving that *FB*=*GH* proves that the balance line quantity is in fact the required availability.

AE=*FG*=*D*	Construction
EF=*EF*	Identity
AF=*EG*	= + = give =
AB parallel to *EH*	Construction
Angle *BAF*=Angle *HEG*	Included angles between parallel lines
Triangle *BAF*≅Triangle *HEG*	Angle—side—angle
Therefore *FB*=*GH*	Corresponding sides to congruent triangles

Therefore, quantity *GH* is the required availability for component *C*.

CUMULATIVE DELIVERY SCHEDULE
(OBJECTIVE)



MONTH	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
CONT.-SCH.							10	20	30	40	50	55
ACT.-DEL.							10					

DATE OF STUDY

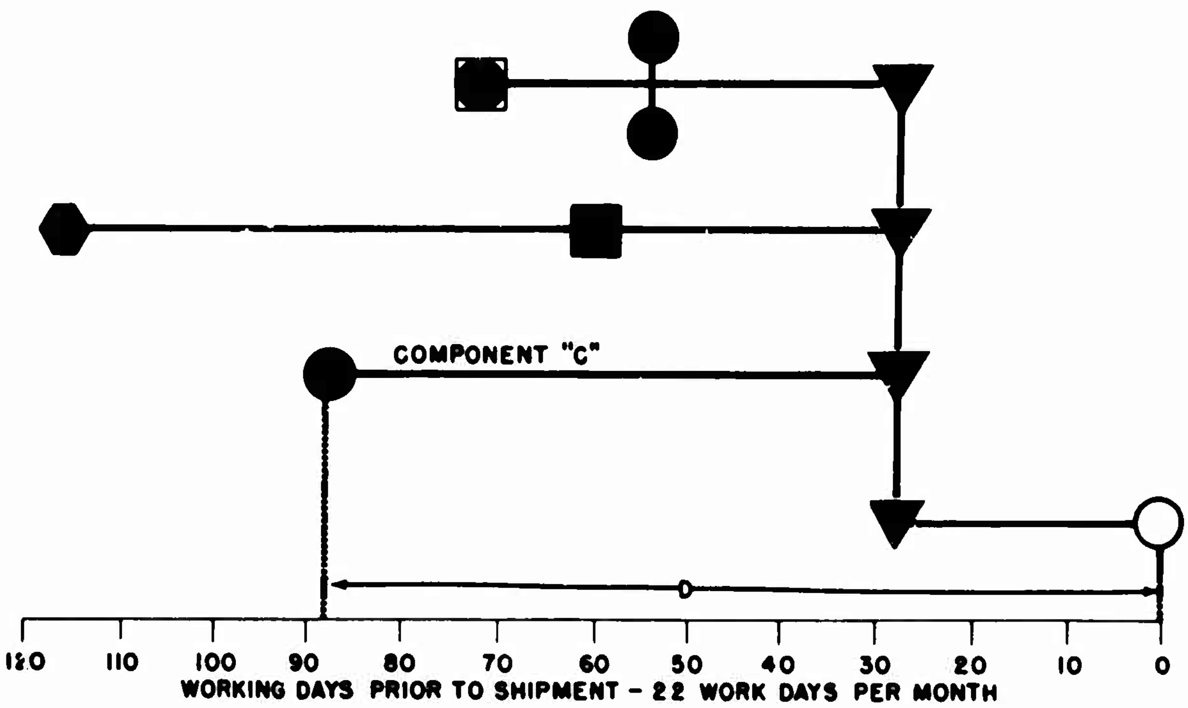


PLATE NO. A

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